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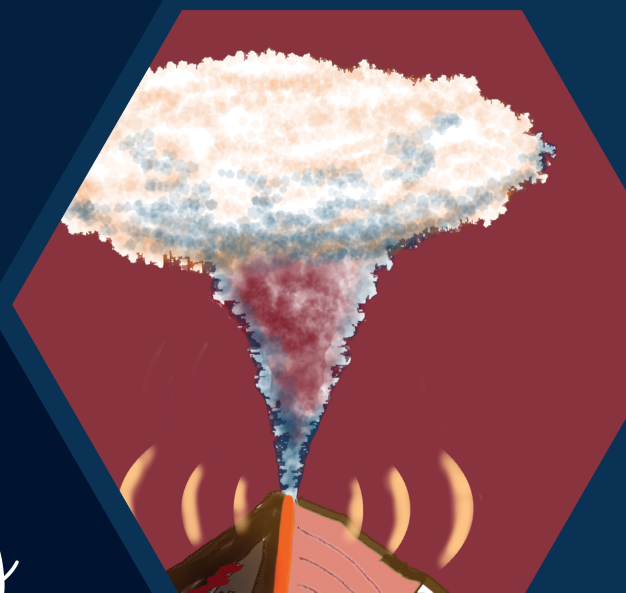

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About the Cover

Images from past cover of *Acoustics Today*. Counter-clockwise from left: Portrait of Lord Rayleigh (Fall 2021), "Drum set" (Winter 2022), "Fearless" (International Year of Sound Special Issue), budgerigar wearing headphones (Fall 2017), and erupting volcano (Spring 2018). Portrait, budgerigar, and volcano graphics by Mark B. Weinberg, Longboat Key, FL. More of the artist's work can be seen at edgieart.squarespace.com. © 2021, 2017, and 2018, respectively, Mark B. Weinberg, all rights reserved. "Drum set" and "Fearless" by Alex Tolstoy. See more of Dr. Tolstoy's art at atolstoyart.com. © 2022 and 2020, respectively, Alex Tolstoy, all rights reserved.

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ASA
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Suite 110
1305 Walt Whitman Road
Melville, NY 11747-4300
Phone: (516) 576-2360

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Serendipity in Acoustics: An Introduction

Arthur N. Popper

"That was a memorable day to me, for it made great changes in me. But it is the same with any life. Imagine one selected day struck out of it, and think how different its course would have been. Pause you who read this and think for a moment of the long chain of iron or gold, of thorns or flowers, that would never have bound you, but for the formation of the first link on one memorable day," **Charles Dickens, *Great Expectations.***

Serendipity: An Introduction

This is my last issue as editor of *Acoustics Today* (*AT*)!

I started editing *AT* in 2014. During my term as editor, I have solicited and edited something like 275 scholarly articles and an equal number of shorter essays and other material, and I have enjoyed every minute of the "job." I have met and worked with a grand array of Acoustical Society of America (ASA) members, learned an immense amount about acoustics and other scholarly fields, and have worked with the marvelous ASA Publications staff.

So, as I thought about my final issue of AT, I decided I wanted to do something a bit different and maybe something that would have very broad interest to ASA members now and in the future. Consequently, after conversations with some ASA colleagues, I evolved the idea of having a set of essays that focus on the topic of *serendipity in acoustics* and more specifically, how serendipity has shaped the scholarly lives and careers of members of the ASA.

Defining Serendipity

Let's start by defining serendipity (since I discovered that not everyone knows the meaning of the word). I like the definition in Wikipedia (see bit.ly/3YQaib5) that says, "*Serendipity* is an unplanned fortunate discovery" and that it "… is a common occurrence throughout the history of product invention and scientific discovery."

But the important thing about serendipity is that it is only of value when it is recognized and followed through. Indeed, serendipitous events happen to each of us all the time, and if we take advantage of any of these events, they can shape our lives. (For example, see the quote above from Charles Dickens, definitely not a scientist!)

But importantly, if a serendipitous event happens, we can only take advantage of it if we have an open mind. Indeed, as pointed out by Busch (2020), "cultivating serendipity is first and foremost about looking at the world with open eyes and seeing opportunities others don't. It's not just about being in the right place at the right time and having something happen to us (blind luck), but rather it is a process in which we can be actively involved."

Serendipity in My Life

Indeed, serendipity has shaped my life, and I am willing to "wager" that if you think about it even briefly, serendipity has had a major impact on your life, and not only as an acoustician but as a person. Just let me give you a few examples of serendipity in my life and see if you have similar, and many other, examples.

More from this author on Across Acoustics

LISTEN

"Save the Fishes!: Offshore Wind Farm Noise and Aquatic Life"

bit.ly/AA-save-the-fishes

https://doi.org/10.1121/AT.2024.20.4.6

In late 1971, a new PhD from Princeton University, Princeton, New Jersey, moved to the University of Hawai'i, Honolulu, where I was on the zoology faculty. Because we were both interested in fish hearing, this fellow, Richard R. (Dick) Fay, contacted me before moving and we "hit it off" virtually instantly. As many ASA members know, Dick and I became the deepest of friends, and we had a truly amazing collaboration for over 50 years. Dick's chance (serendipitous!) coming to Hawai'i profoundly shaped the careers of both of us and led to research and other projects that neither of us would have ever done (or been able to do) individually.

Indeed, one of the most interesting and important parts of our collaboration, came out of a serendipitous moment at a meeting of the Society for Neuroscience, sometimes in the fall of 1978. I happened to be wandering the exhibit hall and looking at books from the publisher Springer. I started chatting with a senior Springer editor at the exhibit. I mentioned that Dick and I would be organizing a session at the 1979 ASA meeting in Hawai'i and wondered if Springer would be interested in publishing the proceedings. The editor was very interested in the idea, and Dick and I published our first book (Popper and Fay, 1980). And this led to further collaboration with this editor and his successors. Had I not had the serendipitous meeting with Mark Licker, Dick and I would not have published our first book, or the 85 that came after it. (We discuss the history of our books in Fay and Popper, 2014.)

Then, in 1975, I went on sabbatical to the Kresge Hearing Institute at the University of Michigan, Ann Arbor, to learn scanning electron microcopy (SEM) for my work on fish auditory mechanisms. One of the first species I prepared and looked at with SEM were lake trout (a relative of salmon). From the limited literature on the ultrastructure of fish ears, I was expecting a pattern of sensory hair cells pretty much like those in homologous inner ear structures in all other vertebrates, including mammals.

But as I scanned the lake trout ear one day, I noticed a very different hair cell pattern; although the cells in the saccule (a vestibular organ in mammals) were pointed in two directions, those in the trout ear appeared to be in at least four directions. I vividly recall sitting at the SEM trying to convince myself I was seeing an artifact, and then a serendipitous thought hit me; I realized I was seeing a pattern in the ear that no one had ever imagined or seen, and then I realized that what I was seeing explained how fishes can determine sound source direction (sound source localization). I recall that this whole thinking process lasted maybe 10 seconds and that I left the SEM laboratory practically dancing down the hall in excitement!

I could go on with serendipity in my life, but I prefer that you read what others have to say about their serendipitous experiences. The real point is that if you reflect on your lives, you will "discover," I suspect, that life takes unexpected twists, as suggested by Busch (2020) and by Charles Dickens.

But, far more importantly, the real lesson is that we, at all stages of our scholarly careers (and in our lives, of course) benefit from being open to serendipity. How open one is shapes one's life, and although sometimes a serendipitous event may not be something you want to pursue or you just ignore, at other times, it leads you into new, exciting, and amazing directions. Indeed, as I think of it, maybe there is a companion term, "what if"! What if Dick had not come to Hawai'i? What if I had not gone to Ann Arbor for a sabbatical? And so on.

The "bottom line," at least in my view, is that serendipity has shaped my life, and if you think about it, you will perhaps realize how important serendipity has been, and is, in your acoustic life.

Closing: Part 1

As I close this essay, and my tenure as editor of *AT*, I am going to take the opportunity to say thanks. First, to all the people who have written articles and essays for the magazine. Sure, a few have been "pains" to work with, but 99% have been grand to work with, and I value meeting so many interesting and truly smart colleagues.

Second, I thank all those ASA members who have provided guidance, help, and ideas when I reached out to them with a problem or question. In particular, I have a small cadre of people (I will not mention names, but they know who they are) who, every time I have asked, freely shared great thoughts, sometimes providing new ideas, sometimes collaborating in generating ideas, and sometimes telling me that ideas I have come up with are dumb! I am most grateful for this help and for great friendships.

Third, I have had the good fortune to work with amazing people at ASA Publications in my term as *AT* editor. Jim Lynch, editor in chief of ASA, is a gem to work with (and he continues as a great and valued friend), and Liz Bury, the ASA Publications Managing Editor is a wise, thoughtful, and a grand person to work with.

Of course, the most important ASA person working with *AT* has been Editorial Associate Kat Setzer. Kat is an amazing asset to *AT* and ASA and, she is a delight to work with and no one could be more effective in getting things done creatively and effectively. And Kat is a grand collaborator and, most importantly, a wonderful friend.

Finally, I thank Micheal L. Dent, associate editor of the magazine for most of my time as editor. Micheal has been a grand collaborator and wise editor. Besides doing special topics (such as "Conversation with a Colleague"), Micheal has reviewed and contributed to every article, often making important suggestions that improved the material considerably.

I also thank my old friend William A. Yost for always being willing to discuss ideas, provide guidance, and serving as a most important advisor in my years as editor of *AT.* And, in particular, I want to thank Bill for serving as "special" associate editor in helping to review and provide advice for many of the articles in this issue.

Closing: Part 2

When I took on the role of editor of *AT,* it quickly became apparent that the ASA Publications staff, with all their responsibilities, could not take on the very demanding role of copy editing the magazine. Sure, we could have edited *AT* the same way as most scholarly publications are edited, badly, but I refused to have that. My feeling was that if ASA was to be represented both to members and to others wanting to learn about acoustics, it should be the highest quality magazine possible. So, I asked Jim to permit me to hire a copy editor who would focus deeply on the details of each article and each word in *AT* to make sure that what you read is as carefully produced as possible. Jim agreed.

Fortunately, I did not have to look very far because I already knew (and lived with) a highly expert scientific copy editor, my wife Helen. ASA approved Helen taking on this role, and I am very proud and grateful for the difference she makes in every issue.

Years ago, I read an essay by the chief copy editor of *The New Yorker*, one of the best English-language weekly magazines in the world. She wrote that the best copy editors are those who can just look at a page and, without even focusing on what it said, just "see" errors. Well, Helen is in that category; give her anything to read, whether it be *AT* or *The New York Times*, and she senses errors and things that can be improved and she is pretty much always right!

So, I thank Helen; she not only does an extraordinary job with editing, but she really cares about *AT* and wants it to be the best it can be. And meeting Helen many years ago was the best serendipitous event of my life!

This Issue

I do want to end with a brief overview of this issue. When I came up with the idea, I decided I wanted to have authors who span ASA in as many ways as possible. After some thought, I decided to reach out to friends in ASA and, in particular, past authors of *AT* articles and also try and ensure that most technical committees (TCs) were represented. If I did not fully succeed in spanning the diversity of ASA, that is partly because we have some limits in the number of essays we could include. Then, a number of people I really wanted to do essays had other obligations that would not allow them to participate or they dropped out between the time they agreed to do the essay and when it was due.

As you will see, there is a very broad range in approaches to these essays and in authors' interpretation of serendipity (authors did not have to adhere to my definition above). Some of the essays are a bit technical, whereas others are much more causal and incorporate life beyond scholarship. But unlike material in past issues where we edited very heavily, in this issue, we have edited only lightly so that the essays would much more retain the "voice" of the authors.

Now for a brief explanation of the next essay, by Steven Weinberg; No, not the Nobel Prize winner but my oldest and closest friend. Steve is a very highly regarded and nationally known science educator (for elementary and high schools) and textbook author. I invited Steve to contribute because I wanted to demonstrate that serendipity in science is not just what we do in our ASA professional lives, but it extends to other aspects of science and, most notably, to the education of the next generations of ASA members.

One other thing to note in this issue is that we have used past *AT* covers when we had a bit of extra space. These covers, all of which link to their issue online, represent the five images on the cover of this issue, as well as a few others that appeal to us (and for which we could get copyright permission easily!). These covers represent the many we have done in the past 10 years. And we thank all the authors (and the artists) for providing us with stunning images that make each issue of *AT* striking.

Final Words

I very much hope you enjoy these essays and hope that in reading them, you will see, and appreciate, that one of the most remarkable things in life is its serendipity. And thanks to ASA and to its members for allowing me to take leadership of *AT*. This has truly been one of the most rewarding and enjoyable "jobs" I've had during my career.

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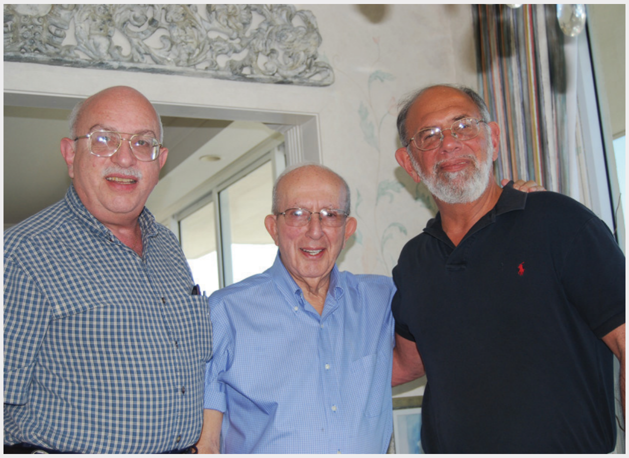
Contact Information

Arthur N. Popper
apopper@umd.edu

Department of Biology
University of Maryland
College Park, Maryland 20742, USA

Serendipity in Science Education

Steve Weinberg



Left to right: *Art Popper, sixth-grade teacher Tom Vinci, Steve Weinberg.*

When my oldest friend, the soon-to-be-retired *Acoustics Today* (*AT*) editor, asked me to write an essay about serendipity for the magazine, I reminded him that I was not a scientist. He, in turn, told me that as a science educator, I had probably a few things to say about serendipity in my life as an educator and about science education in the United States. And, as usual, he's correct. Science education, if done well, does not shove factoid after factoid at students for regurgitation on exams, but rather science education stimulates a wonder for nature and a propensity for asking questions. But how do we get there?

I would also argue that we have failed miserably as scientists and as science educators. Why, for example, do a significant number of Americans have no faith in science? Just look at vaccine hesitancy, climate change deniers, and rejection of evolution in favor of creationism. Or take my favorite, that the moon landing was a hoax. If we as scientists and science educators did our jobs as they should be done, these all would be considered jokes for late night television. Not just science educators but practicing scientists should, and must, engage with students and the public. Science should not stop when the scholarly paper is published!

In thinking about writing an essay on serendipity in my career, I realized that I first needed to see how serendipity is defined. My old, now nearly extinct, print dictionary defines serendipity as "the unexpected occurrence of or faculty for finding valuable or agreeable things that are not sought." My thesaurus listed "happy chance, accident, fluke, luck, good fortune, and coincidence" as some synonyms for serendipity. So, it occurred to me that we all have serendipity in our lives if we recognize it as such or not. Serendipity can be passive or active. Passive if we have no control; active if we're looking for something. If we are prepared for the serendipitous event, we have a eureka moment that I'll share below and that the other authors in this issue illustrate in their scholarly careers.

Serendipity can also be positive or negative. In fact, the inquiring mind is prepared for serendipity. Serendipity can occur in many forms. It may simply be an accident, a person being in the right place at the right (or wrong) time!

Think about when you met a friend or your spouse for the first time. What brought you to that location at that time? Was it something you did consciously or was it thrust on you? A significant serendipitous event in my life was that Art Popper and I were assigned to the same third-grade class at Public School 152 in the Inwood section of Manhattan (north of Washington Heights; at 200th street!). Little did he or I know that it would lead to a lifelong friendship and collaboration and that about 70 years later, he would ask me, a science educator, to contribute to a science magazine on acoustics.

Certainly, one of the most important cases of serendipity in both of our lives occurred in the same school. Public School 152 had six grades (no Kindergarten), and there were several sixth-grade classes. Serendipitously, Art and I were assigned to a class taught by Thomas A. Vinci. Years later, the formality gave way to a friendly "Tom" as you can see in the photo. Mr. Vinci was an amazing teacher, with a deep love of science, and science was the focus

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of many lessons. In thinking back, it is clear that the enduring influence of Mr. Vinci's teaching is evident in his numerous former students who pursued careers in science, science education, or other science-related fields because of the way he made science an exciting adventure. But had Art and I not been assigned to Mr. Vinci's class, our lives (and those of many others in the class) would be very different today (and *AT* would have a different editor!).

Serendipity is personal and occurs in several arenas: science, accidental, personal, positive and negative, and perhaps several more that you can think of. In his book, *Sociology of Science: Theoretical and Empirical Investigations,* Robert K. Merton (1973) discusses the concept of serendipity as an important factor in scientific discovery. According to Merton, "serendipity refers to the unexpected discovery of something valuable or significant while in pursuit of something else."

Serendipity can occur in many aspects of life, including scientific breakthroughs and creative thought to personal relationships and daily encounters. ChatGPT told me that "serendipity emphasizes the role of chance and open-mindedness in making unexpected and positive discoveries." It can bring a sense of joy and wonder to our lives.

This joy and wonder in my life arose from my complaining at a meeting to floating weightless a few months later. A tale of serendipity in the life of an educator. How did that happen? You'll have to read this short tale from a nonscientist to find out.

The arc of my career went from being a high-school biology teacher to science department chair, to ultimately becoming the science consultant for the Connecticut Department of Education and assisting the National Aeronautics and Space Administration (NASA) in developing educational programs for the International Space Station. Along the way, I had some interesting, some would say, serendipitous, experiences.

I began my career as a biology and general science teacher in what by chance was a progressive school system in Connecticut. In the 1960s, the United States National Science Foundation funded several inquiry-oriented science programs. My first-year teaching, beginning in the fall of 1967, was also the first year my school system adopted the use of the Biological Sciences Curriculum Study (BSCS) biology program (see bscs.org/our-work/what-we-do). These programs emphasized inquiry-based learning that encouraged students to ask questions, investigate phenomena, and actively engage in scientific processes. Students were to learn through hands-on activities and exploration rather than passive reception of information. The program was training students to be prepared for serendipity.

Let me share what I think is an interesting example of serendipity that occurred when I was a school administrator. I was observing a fourth-grade teacher giving a great science lesson, asking questions, and challenging and pushing her students to explain some phenomena. (In my dotage, I forget what the lesson was about.) One young boy was really into the lesson, obviously very excited about the material. Toward the end of the lesson, the teacher handed out a worksheet for the students to summarize their thoughts. I noticed that the young man who had been excited just sat there staring at the sheet. I walked over to him, praised him for asking thoughtful questions, and asked him why he wasn't completing the worksheet. He said, "the page is blank." Clearly, it wasn't. On a whim, I took another piece of paper and wrote out the questions with a pencil. He immediately got to work. What was going on?

This was a young person who sometimes did great work; other times nothing. Many teachers (remember this is the early 1970s) used ditto sheets for students to use. The spirit duplicator, or ditto machine, copies by transferring ink from a master sheet to other sheets using alcohol-based fluid or spirit. Ditto sheets were almost always a particular shade of purple/blue. It turned out that the student was colorblind to this shade of blue. By switching to using a pencil or black ink, the student went from being a mediocre performer to being one of the top students in his class. My being in that class that day probably turned a student's life around. Serendipity! This very well may have been a known form of colorblindness. For one reason or another, we never pursued it. The internet obviously was not in our vocabulary.

As the science curriculum specialist for the Connecticut Department of Education, I had the opportunity to attend several national education conferences. At one conference, I attended a workshop run by NASA. To say that the workshop was "awful" would be kind. After the session, I was venting my feelings about a wasted 90 minutes to a colleague. Serendipitously, the Director of Education for NASA heard me complaining (and yes, I was embarrassed) and asked me to join him for a cup of coffee. To make a long story short, a few months later, he invited me to take a one-year leave of absence from the Department of Education and go to work for him at NASA headquarters in Washington, DC, to help create an educational program so that public school students could learn about the International Space Station (ISS).

While I was at NASA, he wanted me to be sure to fully understand as much as possible about NASA. Of course, NASA trains astronauts to work in a microgravity environment using a modified Boeing 727 that flies a series of parabolas to create about 30-35 seconds of weightlessness on each parabola. To my delight, I was invited to go for a ride with a small group of astronauts. The moral of the story: complaining and serendipity may lead to weightlessness.

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Contact Information

Steve Weinberg
weinberg@ntplx.net

Boynton Beach, Florida, USA

A Series of Fortunate Events

Tessa Bent

Serendipity has deeply shaped my research and indeed the trajectory of my career. The first serendipitous turn happened during my undergraduate years at Millersville University, Millersville, Pennsylvania, when I unexpectedly discovered linguistics, the field that I have now been a part of for 26 years.

I started at Millersville as an elementary education major. A few semesters in, I changed my major to English education, keeping my plans to become a teacher but now expecting to teach English at the high-school level. English education majors were required to take several linguistics courses. I hadn't ever heard of linguistics, but the courses were required so I signed up for my first one.

On taking that first course, "Introduction to Linguistics" with the feisty Bonnie Duncan, I knew that linguistics was the field that perfectly combined my love of language with a scientific approach. I had unintentionally set my career path in a new direction. Although I didn't seek out linguistics, from my first class I actively built on that experience by taking all the linguistics courses Millersville offered, most of which focused on historical linguistics. Then, during my senior year, I applied to PhD programs in linguistics.

Because the linguistics courses offerings at Millersville were fairly limited, I only had a general sense of my research interests when I applied to graduate school. Beyond that, I was open to exploring different subfields. I didn't go to graduate school planning to work with a specific mentor or go there seeking what would ultimately become my research specialty, but my receptivity to exploration allowed me to eventually find my research area.

At Northwestern University, Evanston, Illinois, every linguistics PhD student took classes in the major subfields of linguistics in their first year (see linguistics.northwestern.edu). Throughout my first two quarters, I enjoyed many of the classes, especially syntax, but in the spring 1999 quarter, I unexpectedly found the area that became my true research calling.

That spring, I took a seminar with Ann Bradlow (see bit.ly/3W3V92H) that focused on speech perception. Ann eventually became my research advisor and speech perception my research focus. However, I certainly didn't go to Northwestern expecting to study speech perception because I didn't even know what that was before Ann's class. I also didn't go to Northwestern to work with Ann because when I applied to Northwestern, she was not yet on the faculty.

In fact, Ann was deciding to join the Linguistics Department at Northwestern at the same time I was applying to graduate schools. The serendipity of Ann and I both choosing to join the same department at the same university at the same time was one of the most fortunate turn of events that set my career on the path it continues on to this day. Ann's and my parallel decisions not only led me to my research specialty but also connected me with my research advisor, mentor, and now cherished friend of over 20 years.

In Ann's class, we read both seminal and current research articles in the area. I was enthralled by learning about classic findings, such as the McGurk effect (McGurk and MacDonald, 1976) and categorical perception including

More from this author

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"Communication in Medical Settings"

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https://doi.org/10.1121/AT.2024.20.4.13

work investigating the phenomenon in animals such as Japanese quail (Kluender et al., 1987). I was perhaps even more fascinated to learn about Ann's own recent work on second language speech perception, such as successfully training Japanese listeners to perceive and produce the distinction between /ɹ/ and /l/ (e.g., Bradlow et al., 1997), which is a notoriously difficult task.

Ann and I began working together soon after I took that first seminar. During my time in graduate school and beyond, we conducted research on how listeners' and speakers' language backgrounds impact communication success. Some of our most impactful publications were also some of my first.

My first publication focused on clear speech. Clear speech is the speech style speakers produce when asked to speak clearly like they are trying to communicate with someone who is learning the language or is hard of hearing. We investigated how clear speech was perceived by L1 (first language) and L2 (second language) listeners (Bradlow and Bent, 2002).

My second publication with Ann was my first article in which I was first author. In this paper (Bent and Bradlow, 2003), we reported results of testing how the language background (L1 vs. L2) of both the speaker and the listener impacts communication success. We coined the term "Interlanguage Speech Intelligibility Benefit" (now known as the ISIB). Our findings showed that communicating in an L2 is not always a disadvantage, as it is sometimes portrayed, since a shared "interlanguage" (i.e., the system of an individual still in the process of acquiring their L2) between a speaker and a listener that may support speech understanding.

My research in the following 20 years (see bit.ly/4cYNlq8) has expanded in various directions from these first studies with Ann, including, most significantly, investigating how children learn to perceive speakers with different L1 and L2 accents, but it is still fundamentally tied to the core questions and issues that I learned about in my initial seminar with Ann and the studies that Ann and I conducted during my time in graduate school. Although I didn't go to Northwestern planning to study speech perception or expecting to work with Ann, my openness to different subfields allowed me to pursue an unexpected path that has brought me much fulfillment and satisfaction throughout my career.

The next significant serendipitous moment that impacted my career also involved Ann and happened at my second Acoustical Society of America (ASA) meeting, the Fall 2001 meeting in Fort Lauderdale, Florida. Ann encouraged me to attend the Speech Communication Technical Committee (TC) open meeting. I really didn't know anything about the purpose of the meeting or why I should go, but I was eager to learn more about the Society, so I went.

At the meeting, the Speech Communication TC chair, Diane Kewley-Port, asked for a volunteer to join the recently formed ASA Student Council (see asastudents.org). The previous representative from Speech Communication was leaving the Council and they needed a replacement. Because the Student Council was quite new at the time, there were not the standardized procedures for applying to serve on the Council as there are now, so Ann encouraged me to raise my hand to volunteer and I was in!

The serendipitous decision to attend the TC meeting led to serving on the Student Council for three and a half years. During that time, the Student Council substantially expanded support for students in the Society, including offerings that are still part of the Student Council's current work, such as expanding the student reception, offering workshops on topics such as grant writing (the first one of which I planned), and organizing an informal student outing. Our focus was to make the Society even more inviting and supportive for student members; even then we knew that students were the future of the Society.

Throughout my years on the Council, I learned about the structure of the ASA and how to advocate for the needs of our constituents. For me, like others who served on the Student Council during that time, this opportunity opened many doors for continued engagement in the Society and development of leadership skills. After my time on the Student Council, I continued to serve the Society in a range of roles, including Executive Council member, chair of the Member Engagement Committee, and chair of the Task Force on Member Engagement and Diversity. My time on the Student Council, resulting from my serendipitous decision to go to a meeting, informed how I approached much of the work I conducted in the realm of member engagement, specifically the focus on early-career members.

The Student Council had built a solid infrastructure for students, but I saw a need for continued support for our members as they transitioned into the early-career stage. To promote this mission, I coorganized a range of events for early-career members, including three Early-Career Acoustician Retreats, publishing and grant workshops, and speed networking events; several of these were coorganized with David Bradley, who I first met while serving on the Student Council.

When I note who has been in leadership positions within the Society over the past few years, I see many familiar faces of those who served on the Student Council with me. For example, one of my fellow Student Council alumni, Tyrone Porter, who is currently ASA vice president, and I served on the Executive Council together from 2018 to 2019. The connections I made on the Student Council haven't led only to service opportunities but also to research collaborations that during our Student Council days, we never would have anticipated. For example, one of my current research projects, which focuses on the communication in healthcare settings, is in collaboration with Erica Ryherd (Bent et al., 2022). This work began 15 years after we served on the Student Council together.

That one decision to raise my hand and volunteer at a TC meeting allowed for these fundamental leadership opportunities that I continue to build on today and research collaborations, but the serendipity of that event doesn't end there. The TC chair during my first TC meeting, Diane Kewley-Port, would also play an extremely important role in my career, including as one of my mentors and collaborators (Bent et al., 2010) during my postdoctoral fellowship at Indiana University (IU), Bloomington. When I later became a faculty member at IU in the Department of Speech and Hearing Sciences (now the Department of Speech, Language, and Hearing Sciences; see sphs.indiana.edu), I eventually took over Diane's office and laboratory following her retirement three months before I joined the department.

Although I didn't choose Northwestern because of Ann, her serendipitous arrival aligned with mine and influenced my career in an untold numbers of ways I never could have anticipated as I was first embarking on my graduate studies. Reflecting on the early days of my career, there are many other chance meetings and fortunate occurrences that have led me to where I am today. Although serendipity certainly played a substantial role in my career, I also see how my trajectory has been molded by my active decisions to take advantage of the opportunities that presented themselves. Even seemingly small acts like raising my hand during a meeting have had profound impacts downstream on the doors that have opened and the new opportunities that have materialized. At times, these occurrences seem like lucky happenstance, but there is a throughline of decisions that have connected me to the people and places that have brought me deep fulfillment in my career and some of my most important lifelong friendships.

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Contact Information

Tessa Bent
tbent@iu.edu

Department of Speech, Language, and Hearing Sciences
Indiana University
2631 East Discovery Parkway
Bloomington, Indiana 47408, USA

Serendipity in a Multidisciplinary Acoustic World

Jonas Braasch

Introduction

The goal of this essay is to compare the role of serendipity in various fields of acoustics and music from my personal experience (see **Figure 1**). For this essay, the relationships and what you can deduce from my examples are more important than the research findings themselves. I tried my best to give a summary of each finding, but some of the models are very technical. The references provide a complete description for readers interested in specific details. I organized the essay according to my research interests and topics.

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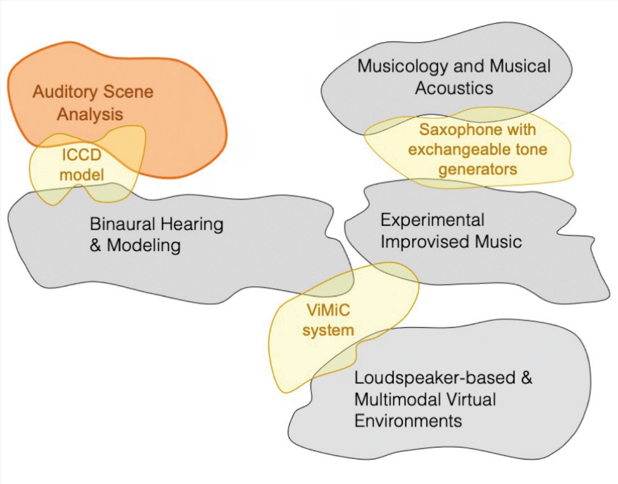
Physics

When I entered college in 1992, I was not sure what career I would like to pursue, so I studied physics in Dortmund, Germany, to be broad enough to figure out a career path later. About a year and a half into my studies, I spent a lot of time in the library studying for my oral pre diploma math exam. Near the end of the day, I often found myself wandering between columns of books. One day, a long shelf of books with light blue backs caught my eye. Serendipity struck me, and I picked up a book in the middle of the blue row, which turned out to be the proceedings of the German Acoustical Society. I realized that many of the articles came from a few laboratories, including Jens Blauert's nearby Institute of Communication Acoustics at Bochum University, Bochum, Germany. I started getting excited enough to check out the Bochum University course catalog and, then, took Jens' courses. Studying with Jens was great. He was a true pioneer in binaural technology, very supportive, and super precise with scientific language. Looking back, serendipity worked well for me by meeting future mentors by chance. I think the main reason for this is I had never predetermined goals but went with the flow of matters that excited me.

Figure 1. *Research areas with mentors I came across during my career (**gray areas**). **Yellow areas** highlight the three research examples where serendipity played a role. ViMiC, virtual microphone control [system]; ICCD, interaural cross-correlation difference (model). **Red area** depicts the field, Auditory Scene Analysis, I was not engaged with at the time of the research finding.*



Engineering, Communication Acoustics, and Musicology

In parallel to physics, I studied musicology at Bochum with Christian Ahrens and later wrote a doctoral dissertation

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on free reed stops in pipe organs (Braasch, 2004). I soon became interested in ethnomusicology and musical instrument studies, and I valued that these studies aligned well with my studies in saxophone performance. Christian was one of the most diligent humanities scholars I have met, and his profound expertise was complementary to Jens in many ways.

When I studied musicology, the *Institut de recherche et coordination acoustique/musique* (Institute for Research and Coordination in Acoustics/Music; IRCAM), Paris, France, was somewhat the holy grail for avant-garde music worldwide. I started to read IRCAM's research publications, and I really enjoyed Stephen McAdams and Emanuel Bigand's book *Thinking in Sound*, which resulted from an IRCAM workshop. The whole book really bridged perception and avant-garde music practice very nicely, something I was both interested in. In particular, I was fond of Al Bregman's (1993) chapter on "Auditory Scene Analysis" in this book. By the time I read Al's chapter, I had become a doctoral student of Jens (starting in 1998). Reading the chapter, it suddenly struck me that I could apply this seemingly unrelated topic to my PhD research on modeling auditory localization perception of two concurrent sound sources. I outline how, thanks to serendipity, I suddenly had the solution for all my problems for this research in front of my eyes.

My initial problem was that I could not predict the perceived lateral location of a target sound in the presence of a secondary sound, the distracter, when both overlapped spectrally. Human listeners have no problems performing this task, but when I examined the interaural cross-correlation patterns, the most common method to simulate auditory localization processes, I just saw a very undefined interference pattern that, on average, suggested a single sound source that was located in between the actual two sounds, the target and the masker.

Bregman's (1993) auditory scene analysis theory explores how listeners can extract information from complex multisource sound patterns. One essential concept I came across reading Bregman's book chapter is the old-plus-new strategy, which states that listeners often assume that the old sound is ongoing when a new sound arises. In nature, sound properties of unrelated sounds usually do not change abruptly at the same time. I realized that I ignored an essential part of my experiment, namely, that my distracter needed to precede the target so the listener could distinguish the target from the distracter and correctly identify the target location. With this insight, I could easily predict the perceived location of the target by subtracting the interaural cross-correlation function of the preceding distracter part from the average interaural cross-correlation function of the part when the target and distracter overlapped. I should note that in this experiment, the target was never presented to the human listeners in isolation. To provide further evidence that this model was an adequate predictor of human perception, I could show that listeners were not able to localize the target when the preceding distracter portion was removed. Once I connected my problem to Bregman's old-plus-new strategy, it took me less than a week to create a proof-of-concept model and then, of course, it took me about a year to work out all the details for a publication (Braasch, 2002).

There is an old joke that the difference between a generalist and a specialist is that the specialist knows everything about nothing and the generalist knows nothing about everything. I see myself as a multispecialist with a few areas of expertise that drift through space and time, like tectonic plates, and sometimes they align in a funny way. Then serendipity sometimes makes the connection, forming the bridge to a new concept.

Sound Recording

Engineering solutions are often found by transferring a solution from one field to another. The circumstance in which I developed the virtual microphone control (ViMiC) system was also a series of lucky coincidences. When Jens retired, a position in music technology at McGill University, Montreal, Quebec, Canada, caught my eye because it was related to my work on pipe organs. Wieslaw Woszczyk, the chair of McGill's Sound Recording Department, liked Jens' research and thought it would be worthwhile to interview one of his students.

At that point, I had some experience recording my own music but no formal training in this area. A friend recommended reading Dickreiter's (1997) seminal book that I read on my flight to my interview. One thing that was completely new for me was the concept of main stereo microphone techniques where the sound engineer strategically places two microphones such that the sound delay and intensity differences between both microphones translates to interchannel time and level differences. The latter allows listeners to localize sound sources left and right when the recorded stereo microphone signal is presented via two loudspeakers placed at a 60° angle in a typical stereo system. I realized that the related math was not that different from dealing with head-related transfer functions (HRTFs) in binaural technologies for headphone-based sound.

After getting the job at McGill, I started to implement main microphone techniques into a real-time virtual environment using the techniques we developed at Bochum for HRTFs and named the system ViMiC (see, e.,g., Braasch et al., 2008). We set up the ViMiC system in McGill's 24-channel audio system, and the system offered similar flexibilities to shape the width and character of an auditory image that recording engineers know from their sound recording practice, whereas other common spatialization techniques were more concerned with accurately reproducing just the directionality of the rendered sound.

Architectural Acoustics and Experimental Music

Pauline Oliveros (see bit.ly/4e25AMl) was another important mentor in my life. I met her in 2006 when I started an assistant professor position at Rensselaer Polytechnic Institute, Troy, New York, in architectural acoustics. Pauline was a world-class composer and improviser. She founded a well-known practice called *Deep Listening,* which is based on critical listening, breaking conventions, and intuition. Pauline was probably the most intuitive person I met in my life. She was a pioneer of modern artistic research, and her work is a good example of how serendipity can play a different role in the arts from that in science or engineering. Pauline was an advocate of not practicing music material because she claimed that one would only fall into repetitive patterns.

Having had prior experience in freely improvised music, I decided to help Pauline co-teach her graduate music ensemble class. The way Pauline thought and practiced artistic research was fundamentally different from anything I had experienced before. If science is dedicated to understanding the laws of the universe and learning how it operates, engineering finding technical solutions to known problems, and humanities to understanding historical trends in social interactions, artistic practice was something I had much more difficulty with grasping it formally. If I come back to the idea of comparing my research areas to "tectonic plates" that loosely drift aside from each other, a common artistic practice is to try to push one's plate as far into unknown territory as possible.

This can be done, for example, by installing a new framework with unknown consequences. A good example is the invention of quarter-tone music, where one divides the octave into 24 instead of 12 equal-tempered intervals and sees what the perceptual/artistic consequences are. Pauline's approach was the opposite, removing known frameworks and letting intuition navigate music in uncharted territory. Serendipity does not play a big factor in this because you are technically not finding something other than what you are looking for because you are not specifically looking for something.

However, you can still find a lot of new things accidentally. Pauline, Doug Van Nort (see dvntsea.com), and I had a free improvisation trio, *Triple Point*, from 2008 until her death at age 84 in 2016 (Triple Point, 2014; see also bit.ly/3UDmB7M). Her two regular complaints with me were that the saxophone was too loud (that's why Adolphe Sax invented it) and that I was overthinking everything (probably the physicist in me). One day, I got myself in trouble because I found no time to prepare myself for a saxophone solo concert at the Deep Listening *Dream Festival*. The only option I had left was to follow Pauline's advice to let go and not think about anything during the solo. After the concert, Pauline simply commented, "*You finally got it.*"

Later, serendipity played an important role in my artistic work. My two major concerns about my own saxophone performance in *Triple Point* were the lack of sound flexibility and the feeling that I had not developed my unique saxophone practice yet. I became aware of the static nature of the saxophone timbre when Pauline started to use a Roland synthesizer accordion interface that was able to produce any conceivable sound using physical modeling. It did not help that Doug as an electronic musician who works a lot with sampled sounds and granular synthesis, among other techniques, also had an endless repertoire of different sounds and timbres.

One day, I was preparing a section on nineteenth-century wind instrument practice for the aural architecture class

I was teaching when I came across the story that Adolphe Sax was also a brass instrument builder and often interchanged concepts between brass and woodwind instruments. In fact, the saxophone had much in common with the ophicleide, an early nineteenth-century brass instrument with keys. It suddenly occurred to me in a serendipitous moment that I could simply replace my saxophone mouthpiece with other tone generators as part of my experimental music practice to get a lot of different sounds. It took me many years, though, to learn to play all my tone generators, and I eventually wrote a book titled *Hyperspecialization in Saxophone* about it (Braasch, 2019; listen at vimeo.com/898780205).

Independent of the academic field, we try to maximize our creative output. Serendipity can be very effective in this context. In my experience, research stemming from serendipity often falls into the risky research category. I remember that after practicing my different tone generators for about five years, I sat there in disbelief and asked myself why I was so persistent without even knowing if this would ever lead to something useful one day or not.

On the opposite side of serendipity, I sometimes found myself willfully ignoring important things around me in my career to stay focused. For this reason, I did not really dive deep into Pauline's Deep Listening philosophy. In 2015, she insisted that I participate in her Deep Listening certificate program. I was pretty reluctant in the beginning, especially because regular Sunday meetings are not the most family friendly activity to commit to, but in the end, I was very grateful to learn all her fantastic philosophical Deep Listening concepts in the last class she fully taught herself.

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Contact Information

Jonas Braasch
braasj@rpi.edu

School of Architecture
Experimental Media and Performing Arts Center (EMPAC)
Rensselaer Polytechnic Institute
Troy, New York 12180, USA

Serendipity Is the Company You Keep

John R. Buck

*John R. Buck [**center**] with Andy Singer [**left**] and Kathleen Wage [**right**] in July 2024.*

Introduction

There is a hockey cliché that the best saves are when the goalie puts themself in position and just lets the puck find them rather than reacting to the shot. I believe the same applies to serendipity. Serendipity is more likely to strike when you put yourself in a good place and wait rather than if you actively pursue it. The serendipity I have known has been more in the colleagues who found me than blinding insights. My colleagues have expanded my scientific horizons while challenging me to be my best self. None of these collaborations grew out of deliberate planning but emerged from happy coincidences and thwarted plans that is serendipity. In this essay, I describe the origins of some of my rewarding collaborations and then distill from these experiences four suggestions to improve your chances to find serendipity or have it find you. Finally, I apologize in advance to the many wonderful colleagues that space limitations preclude me from including in this essay.

A career spent studying signal processing offers broad opportunities for collaboration. Every discipline in science and engineering extracts information from signals. Some signal processors choose to stay close to home, focusing on traditional applications such as audio, speech, and wireless communications. Much of my most enjoyable (and according to citation indices, impactful) research has been in animal bioacoustics. This was not the plan. As an undergraduate electrical engineering student, I focused my coursework on signal processing and further specialized in speech processing during summer internships in digital telephony. During my first year of graduate school at MIT, Cambridge, Massachusetts, my advisor, Alan Oppenheim, suggested that I could spend my summers at the Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, if I applied the speech enhancement algorithms I had been studying to underwater sounds. That was all the encouragement I needed to pivot from speech to underwater acoustics.

As I finished my MS degree in the spring of 1991, I planned to take a break from graduate school to teach high school for a few years. I was looking for a summer position to fill the gap before a teaching job would start, and the WHOI Marine Animal Bioacoustics Laboratory, led by Bill Watkins (WHOI, 2004), was looking to hire a signal-processing student just for the summer. That summer in Shiverick House, as the laboratory was metonymically known within WHOI, Peter Tyack (2024) and I developed an algorithm for classifying bottlenose dolphin whistles from their fundamental frequency contours.

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Caldwell and Caldwell (1965) proposed that the fundamental frequency contour of a bottlenose dolphin's whistle contained individually identifying information, making these contours a natural feature for classification. Speech-recognition researchers had previously explored contour comparisons but found that these features were not reliable for classifying human speech or speakers. As chance would have it, I learned about these contour comparison algorithms during my previous summer internships. The serendipity of recognizing that a discarded speech-recognition technique was exactly the right tool for classifying dolphin signature whistles resulted in my first published paper in *The Journal of the Acoustical Society of America* (*JASA*) (Buck and Tyack, 1993).

More importantly, that summer began a friendship and collaboration with Peter Tyack that has spanned two continents, three decades, and four marine mammal species to date. Meanwhile, other scientists following our work applied the contour comparison algorithm to signals from birds, killer whales, fin whales, and blue whales among other species. In the end, I did not get hired to teach high school and continued into the PhD program. But for my thwarted plans to teach high school, I may never have met Peter nor started collaborating in animal bioacoustics.

The Shiverick House lunch table was an informal seminar on the practice and history of marine mammal bioacoustics. During one of those lunches, Tyack described the hierarchical organization of humpback whale songs proposed by Payne and McVay (1971). As he sketched trees and transition diagrams for themes on a piece of scrap paper, I felt something click in my mind connecting these figures to the Hamming codes and Markov models I had studied in my electrical engineering classes. These ideas lay fallow for several years while I completed a more traditional PhD dissertation in ocean acoustic signal processing.

When I started my faculty position at UMass Dartmouth, I eagerly returned to investigating humpback whale songs with mathematical methods from information theory as part of my first National Science Foundation (NSF) grant. Serendipity played a critical role here as well. Just as the NSF grant started, a talented undergraduate student named Ryuji Suzuki contacted me inquiring about a possible research internship. In addition to his strong math skills, Ryuji's amateur radio background gave him extensive practical experience with communication theory and vintage audio electronics. Ryuji soon identified Wyner et al.'s (1998) nonparametric entropy estimator as the tool we needed to analyze the structure of humpback songs.

Adding another layer of improbability, the reel-to-reel tape recordings Tyack had made for his PhD field work were housed at Ocean Alliance, just over an hour's drive from our campus. These recordings contained long uninterrupted songs from a single whale, exactly what we required for entropy estimation. Ryuji's audio expertise allowed him to coax the reel-to-reel tape machine to play the original recordings so we could digitize them, providing hours of humpback song data. The string of serendipitous events that led Ryuji from Japan to a small public university campus in Massachusetts at just the right time with the perfect background to collaborate with me and Peter on the humpback song project would be completely implausible in a novel, but the result was one of the most intellectually exciting interdisciplinary projects of my career (Suzuki et al., 2006).

At the May 2000 Acoustical Society of America (ASA) meeting in Atlanta, Georgia, Doug Cato from the Australian Defence Science and Technology Organisation presented a talk describing the dramatic change in the eastern Australian humpback population song recorded by his PhD student Michael Noad from 1995 to 1998. Serendipity intervened here as well, scheduling Doug and me to speak in the same session and nearly consecutively. Doug and I met for lunch the next day, and we quickly recognized that analyzing their Australian humpback song recordings with our information theory techniques was too promising an opportunity to pass up.

Three years and a successful Fulbright proposal later, I joined Doug, Mike Noad, and others at the Office of Naval Research (ONR)-funded Humpback Acoustic Research Collaborative (HARC) experiments in Queensland, Australia. This month-long field experiment yielded a remarkable dataset of humpback songs as well as a lifetime of memories. Although I am proud of the paper we published (Miksis-Olds et al., 2008), the collaborations with Doug, Mike, and Tracey Rogers were the lasting gifts from my Sydney sabbatical. A few years later, as we enjoyed one of many delightful meals together, Doug first focused my attention on another form of serendipity we too often take for granted. How wonderful is it that a career in science brings together friends born half a world and decades apart?

Reading these reflections may have you wondering: how can you put yourself in a place where serendipity can find you? I have distilled four suggestions for students and young scientists from my own experiences.

First and most important, make space for serendipity. For me, this space is usually physical exercise (a run, a bike ride, or a walk). The time alone (no earbuds!) allows my mind to wander productively. Better still, sharing the exercise and conversation with a friend often spurs both of our thoughts in new directions. Without a notebook or computer at hand, you think conceptually about how the parts of your problem fit together. You stop worrying about the trees and focus on the forest. For example, the breakthrough on the universal dominant mode rejection beamformer (Buck and Singer, 2018) emerged during a long bike ride outside Champaign, Illinois, with Andy Singer of the University of Illinois.

The space for serendipity can also be time. During his years at Bell Laboratories, the mathematician Richard Hamming devoted 10% of each week to reading and thinking about ideas not directly related to his current project (Hamming, 1986). Tech companies such as 3M and Google allow employees to pursue passion projects to boost innovation (Johnson, 2010). Hobbies such as music and art can focus your attention, creating space for new ideas to percolate into your conscious mind.

Second, create space for serendipity in your conversations by learning to listen more patiently. American academic culture trains us to race to answers like a contestant on a TV game show. These habits can hamper interdisciplinary research because we rush to solutions that do not really fit the problem. Bringing interdisciplinary collaborators up to speed provides a great opportunity to step back and reexamine previous assumptions and approaches. Slow down. Ask your colleagues to explain the question they are trying to answer, not the problem they are trying to solve. As you listen, be alert for jargon hiding in everyday language. Be suspicious of words that everyone uses without defining. Words like *active sensing*, *information,* or *coherence* have all sown confusion in projects during my career. Ask potential collaborators to unpack unfamiliar terms for you. Often, you will both learn something when they do.

Third, learn the fundamentals of your discipline as deeply as possible. Making space *for* serendipity won't yield fruit unless you invest the hard work to prepare the intellectual soil for the seeds that fall. Go beyond the formal mathematical incantations. Drill down to recognize the underlying conceptual frameworks behind the notation. This deeper understanding will help you to recognize a problem that you have solved before when it reappears wearing a new set of variables.

Indeed, teaching foundational undergraduate classes is a great opportunity to strengthen your conceptual understanding of your own discipline. I was fortunate that my PhD advisor, Alan Oppenheim, supported and encouraged my passion for teaching. Finding accurate analogies to help the students link the mathematical ideas to everyday experience stretches my creative reach and helps the students grasp the ideas and concepts. Many potential collaborators will have less background in your discipline than the undergraduates you are teaching. Developing your ability to explain the concepts accurately in everyday language opens more doors for serendipitous collaborations.

Fourth, balance your deep understanding of your own field with a broad general understanding of adjacent disciplines. Kauffman (2000) coined "the adjacent possible" to describe the set of things just one step beyond the currently available domain, whether these things be mathematical ideas or chemical compounds. In *Where Good Ideas Come From* (2010), Johnson expands on Kauffman's idea: "The strange and beautiful truth about the adjacent possible is its boundaries grow as you explore those boundaries." Building breadth allows you to expand the boundaries of your adjacent possible. Read journal papers and attend talks in related disciplines. At your next ASA meeting, make time to attend a session sponsored by a different technical committee.

When expanding the breadth of your knowledge, do not try to memorize detailed derivations or complicated notation; challenge yourself to recognize the larger intellectual landscapes. What questions are researchers in that field trying to answer? How do they think about these problems? Where are their approaches similar to those you already know, and where and why are they different? Fowler's (2001) excellent essay on the difference between reading a journal paper and a textbook is a great starting point for this practice of strategic reading. This skill requires mental discipline and practice but will pay dividends if you persist and improve. Scientific serendipity often resides in these interstitial regions between established domains.

Initially, it felt like a serendipitous chance that among hundreds of graduate students in the MIT Electrical Engineering and Computer Science Department, Andy Singer, Kathleen Wage, and I served as teaching assistants in the same classes. In hindsight, I see that this serendipity grew from shared pedagogical instincts. We were excited about project-based learning and conceptual assessment before these approaches were widespread in engineering pedagogy. We also delighted in making the classes fun for the students. Discussing potential exam problems while walking across campus to get lunch grew into runs, walks, and bike rides debating array processing. Brainstorming better MATLAB projects flowed into discussions of underwater acoustic propagation. These graduate school peers blossomed into lifelong friends who bring out the best in me time and time again.

The ground rules for these essays prohibit coauthors, but Kathleen and Andy deserve some credit for the four recommendations I listed above. This advice grew out of our shared lived experience: digging for deeper understanding of signal processing, sharing new ideas we found in neighboring fields, listening thoughtfully to each other, and ruminating on what we had heard. Serendipity combines curiosity, surprise, and delight as we find unexpected new meanings in the world. Andy, Doug, Kathleen, Mike, Peter, Ryuji, and many others have engaged my curiosity and delighted me with surprising new insights. The joy I have found in these friendships is the great gift of my career.

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Contact Information

John R. Buck
johnbuck@ieee.org

Department of Electrical and Computer Engineering
University of Massachusetts Dartmouth
Dartmouth, Massachusetts 02747-2300, USA

Serendipity in My Life

Ilene Busch-Vishniac

I've often thought about what distinguishes scientists from everyone else. It's not our gender, our race, our political views, our religious adherence, our hobbies, or even the food we like. It's nothing about our physical characteristics or our behaviors outside our work. What distinguishes scientists is how little we leave to chance in our work. We hypothesize and test those hypotheses carefully. We calibrate, measure, monitor, analyze, and repeat experiments until we are sure we've determined a result that is real. We compare our theories to known behaviors and to results others have presented. In short, we aim to minimize serendipity in our work.

Yes, there have been accidental discoveries in science. Most people learn in grade school that penicillin was one such discovery because Alexander Fleming went away on vacation in 1928 and returned to find a moldy fungus growing in one of his petri dishes with no bacteria in that specimen. And there are a handful of less well-known but very important serendipitous discoveries.

Matchsticks were invented in 1826 when John Walker accidentally scraped a stick coated with chemicals against his hearth and it burst into flame. William Perkin was looking for a synthetic substitute for quinine, used for malaria treatment, and came up with a purple glob, mauvine, that we now know as the first synthetic dye. In 1878, Constantin Fahlberg, a laboratory worker, went home for supper but neglected to wash his hands before eating (yuck!). Everything tasted sweet so he worked backward to determine that he had discovered a new sweetener, saccharin. Safety glass was invented in 1903 when Edward Benedictus accidentally knocked over a flask in his laboratory and noted that the glass cracked but didn't shatter. Similarly, Patsy O. Sherman invented Scotchgard in 1955 when she accidentally spilled chemicals in a flask onto her shoes. She noticed that the shoes didn't get dirty where the liquid landed. X-rays, Teflon, superglue, microwave ovens, pacemakers, and Post-It notes were all serendipitous discoveries.

But these exceptions to the rule don't disprove my assertion that scientists work to minimize chance. The fact that I can name a dozen accidental discoveries over 200 years hardly eclipses the millions of discoveries that occurred in that time that were methodically sought out. Furthermore, in virtually all the accidental discoveries mentioned here, the discovery resulted in weeks, months, and sometimes years of deliberate scientific research to yield commercial products.

So, if we scientists work to remove chance, what role does serendipity play in our lives? It is in the human interactions we have in our work and nonwork lives that serendipity is important. It is in the accidental meetings that lead to a conversation that changes the course of our work, the opportunities seized on the spur of the moment, and the unexpected things we see and hear that serendipity affects us. There are a few serendipitous events in my life that have been important.

When I was finishing high school and thinking about where to go to university and what to study, I decided to pursue a music degree at the University of Rochester (UR), Rochester, New York, which has a marvelous music program in the Eastman School. However, my parents were not supportive. They foresaw me requiring lots of financial support, not just for the college years but for years of postgraduate life trying to scrape by as a musician. We had many heated arguments about my future, and in the end, I agreed to be a Bachelor of

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Arts in Music student, which meant I'd take academic subjects on the UR main campus and music courses at Eastman.

Off to Rochester I went. My first term I signed up for one of the special, small-enrollment courses that the UR offered to freshmen, the "Physics of Music." I signed up for this as a lark; other small-enrollment courses that interested me were already fully enrolled. I also started piano lessons with one of the Eastman professors, a woman who terrorized me. She yelled at me for saying "hello" to her daughter, who would regularly show up outside her mother's office just before my lesson. I was told by my teacher that her daughter was there to do her homework and not to socialize. By the end of the first year, I had switched to a physics major, based on my love of the "Physics of Music" class, and dropped piano lessons so I could avoid my horrible piano teacher. Had I not taken that freshman course, I would never have found my way to acoustics.

My decision to pursue a physics degree was aided by another chance happening. My freshman-year roommate was a graduate of one of the local Rochester high schools. There were a fair number of other students from Rochester who I met as they stopped by to visit. One of them was Ethan Vishniac (see bit.ly/4g2ERAs), who hadn't exactly graduated high school. He had been given permission by his parents to skip his senior year and head off to college as long as he stayed local so they could keep an eye on him. (He remains a high-school dropout. His school district said they would award him his high-school diploma if he finished two terms of English, and he could stomach only one course.)

Ethan was a physics major and as our relationship matured, moving into a physics major seemed to be a natural decision for me as well. Meeting Ethan, my future spouse, clearly changed the course of my life. At the time, it also changed the nature of my relationship with my roommate, as she eventually figured out Ethan was visiting to see me and not her.

The next major serendipitous event that shaped my life happened with my first academic job. After the UR, I went to the Massachusetts Institute of Technology (MIT), Cambridge, to work with Dick Lyon while Ethan completed a PhD in astronomy at Harvard University, Cambridge, Massachusetts. Next, we moved to New Jersey, where I assumed a postdoctoral position at Bell Laboratories, Murray Hill, New Jersey, and Ethan scored one at Princeton University, Princeton, New Jersey. When the postdocs ended, we moved to Austin, Texas, and began academic appointments at The University of Texas at Austin (UTA).

Starting the first academic job can be quite a challenge. For those of us who enjoy working collaboratively, success relies on finding the right partner. I was fortunate in that UTA had a strong acoustics program when I arrived. David Blackstock and Elmer Hixson were generous with their time and filled me in on their current projects, but their areas of research didn't overlap my interests or talents. I was also introduced to the folks at the Applied Research Laboratory (ARL), a large research laboratory affiliated with UTA. Mostly their work at the time was focused on acoustics problems for the Navy. Again, it was not really aligned with my prior work, but it was interesting.

I was not sure how to find a collaborator and was considering a move out of acoustics to an area with greater representation in my home department when a serendipitous happening changed my research directions. I was approached by Robert Culbertson of ARL and told that he was advising a graduate student but could not continue to do so as his UTA appointment had expired. He wondered if I would take over as advisor on the funded project. I agreed and had my first graduate student, Yves Berthelot.

That chance transitioning of a student had several impacts. It introduced me to a new area of work, as the problem Yves was working on was laser generated sound underwater. It started my academic career with one of the best students I have ever had. Yves was self-motivated and very talented as an acoustician and a musician. It kept me in the acoustics fold rather than seeing me migrate to system dynamics. It also got me started with Navy funding to pursue interesting acoustics questions, an area of research I pursued for many years.

I left UTA in 1998 to join Johns Hopkins University (JHU), Baltimore, Maryland, as the Dean of Engineering. One of the attractions of JHU was their affiliation with the Applied Physics Laboratory, much like ARL at UTA but larger. Universities have all sorts of hierarchical structures. At JHU, the deans were the most powerful people, having complete control of their budgets. The President, Provost, and Vice President for Research had hardly any budget and thus needed the support of the deans to do anything requiring significant funding, in other words, to do anything.

I was not the only female dean because the College of Nursing also had a female dean, but I was the first female dean of engineering at JHU, the first female dean outside of Nursing, and only the third female engineering dean in the country. Not surprisingly, I got to know the other JHU deans but also took time to get to know the other women leaders in the administrative ranks. A group of four of us got to be very friendly. The group included a vice provost, the deans of engineering and of nursing, and the chief information officer (CIO). We'd get together a handful of times a year for dinner and socializing.

In 2003, having grown increasingly frustrated by the sexism displayed by the JHU top leaders and at the end of a full term, I stepped out of the dean position to return to teaching and research. Normally, a university administrator returning to regular academic duties shifts their research area as new work in their original research focus area has passed them by. The idea is to have a fresh start in a challenging area. I had managed to convince Jim West (see bit.ly/3YZibuL) to come to JHU, so I had a collaborator ready to rock and roll.

As I was renewing my teaching, continuing my work on diversity issues in engineering education, and restarting my research, a great opportunity fell into my lap. Serendipity was at work again. I was contacted by my CIO friend who asked me for help. At JHU, all the top administrative leaders with responsibility for anything related to the hospital system are asked to adopt a hospital unit. The CIO had adopted the Pediatric Intensive Care Unit, the PICU, at Johns Hopkins Hospital. She rounded with them once a month and tried to identify any opportunities to intercede to help them resolve issues. The PICU at the time had an L-shaped geography that made communicating difficult. The incessant noise from the medical equipment also hindered communication. What the CIO wondered, was whether I could help the PICU staff resolve the noise and communication issues.

Jim and I agreed to meet with the nurse administrator of the PICU and to tour the unit. We were frankly certain that we'd be able to find work done on hospital noise and connect the JHU folks with the experts in the area, but when we went looking for papers, we couldn't find any acoustics experts on control of hospital noise. Thus, Jim and I began our work on hospital noise control. We had the blessing, and even some funding, from the President of Johns Hopkins Hospital, who agreed that we could publish what we found uncensored.

As another happy coincidence, the president of the hospital had recently had an overnight stay there and couldn't sleep because of the noise. Our work led to a series of papers including what is now my most cited published paper (Busch-Vishniac et al., 2005). Over the next decade, we convinced others to work on hospital noise, and it remains an active research area in the Acoustical Society of America (see Busch-Vishniac and Ryherd, 2019). We have been credited by many acousticians with establishing this important subfield of research.

In each of the serendipitous experiences I've mentioned, the benefits have come from the accidental connections to opportunities that changed my direction. In the first case, the course I took in part because it wasn't fully enrolled and the chance meeting with my future spouse led me to change my major to physics. In the second case, I inherited a fabulous PhD student who led me to work with the Navy on several interesting acoustics problems. In the third case, a request for assistance from a friend and colleague led to the work I did with collaborators on hospital noise.

The strongest learning I've taken from these experiences is to be open to new opportunities. You can never be sure when they will arise or which ones will alter your life's work or nonwork directions. Additionally, as my serendipitous events have come from personal contacts, I've learned that it is critical to develop a network of collaborators, colleagues, and friends who share their problems and successes with you.

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Contact Information

Ilene Busch-Vishniac
buschvi@gmail.com

BeoGrin Consulting
200 Westway
Baltimore, Maryland 21212, USA

My Serendipitous Path to Cochlear Implants

Monita Chatterjee

Early Dream Realized

Growing up in Kolkata (see bit.ly/4dnEnmW), a big, busy, vibrant city in India, I had occasional opportunities to volunteer at a residential institution for children with major neurological and other challenges that often were due to poverty and related causes. Years later, as an undergraduate student in electrical engineering at Jadavpur University, Kolkata (see bit.ly/4dF7xNV), I would reflect on those children and wonder what could be done to help. What could have gone so wrong with their neural systems to affect mobility, cognition, and communication?

These thoughts turned into questions about the brain and neural systems. I found myself reading anything I could get my hands on that discussed the brain, neurons, and neural networks. I hadn't heard the word "neuroscience" as yet, but I was really making up the field in my head. With all the ignorance and confidence of youth, I decided that I would figure out how neurons worked and then come up with a prosthesis that would help people with neurological problems.

Not finding relevant programs in my country, I visited the United States Educational Foundation of India (which fortunately had an office in my city; see usief.org.in/Kolkata.aspx) in my senior year and asked if they had any programs to suggest for an engineer trying to learn about neurons. Needless to say, they had no idea what I was talking about, and I had to find a creative way to get into their "library," a room full of guides to various graduate programs in the United States.

After spending a couple of fruitless days looking through endless programs (neuroscience was mostly for biology majors in the late 1980s and a nascent field even in the United States), a truly serendipitous event happened. A slim white brochure fell out from in between two volumes of college guidebooks and into my hands. It advertised a PhD in neuroscience designed for engineers, physicists, or mathematicians! This was the program that Jozef (Joe) Zwislocki (see bit.ly/3SIxdBl) had founded at the Institute for Sensory Research at Syracuse University, Syracuse, New York. The brochure had a picture of a neuron, with the membrane charging equation (which I identified easily from my engineering coursework). I immediately went about finding out how to apply, took the Graduate Record Examination and the Test of English as a Foreign Language, and somehow got an application submitted for the fall of 1987.

I was admitted to the Institute but having applied too late for financial aid, it all fell through for lack of funding. There was no way my professor parents could afford to pay for tuition and living expenses in the United States (professors were paid very little in India in those days). I hadn't really thought I would get in, the distance between Syracuse and my neighborhood in India seemed simply too vast, but I had been (irrationally perhaps) hoping that it would work out; the negative outcome was depressing.

I started looking into other graduate programs in India and contemplated applying for jobs as an electrical engineer. A few months later, I received a letter from Syracuse University. It turned out that a student they had funded had left the PhD program after a few weeks, and they now had funding for me in spring 1988. This was the best news I could have had. In a few months, I was on my way to my first experience of snow in upstate New York! That program was probably also the best thing that ever happened to me. The serendipitous path, from encounters with neurologically challenged children as a schoolgirl leading to an interest in neurons, the white brochure falling into my hands, and ending with the other graduate student leaving the program, formed the basis of my entire career.

Opportunity to Work at House Ear Institute

At the end of my PhD work, cochlear implants were exploding onto the scene, and I badly wanted to work

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on this neural prosthesis. However, Joe Zwislocki was among those who were skeptical of the whole enterprise and questioned the ethics of implanting children without adequate safety tests, all likely reasonable doubts in the early days. As my PhD advisor, he refused to support this "crazy" venture.

But then, another serendipitous thing happened. As it turned out, Joe had always had a soft spot for Bob Shannon (see bit.ly/4dHEysM) ever since the two had met at a conference and spent some hours talking about shared interests in physiology-based models of psychophysical phenomena, and he was impressed by a talk that Bob gave at the 1994 Spring meeting of the Acoustical Society of America. Returning from that meeting, Joe said to me, "If you work with Bob Shannon, I will support your getting into cochlear implants." I didn't know Bob at all, but I sent in an application and was invited to visit House Ear Institute in Los Angeles, California (see hifla.org). Now, another piece of serendipity had to occur, Bob had offered the open postdoc position to someone else, but that candidate had declined, leaving a position open for me. This allowed me the opportunity to work on the first truly successful neurosensory prosthesis.

One's cohort is always crucial to success but particularly so in the apprenticeship years and in early-career phases. A remarkable convergence of brilliant minds occurred during my postdoc and early years as a scientist at House. We shared a great excitement about cochlear implants, and many new ideas and discoveries emerged from the countless animated discussions and debates in the laboratory.

Work at Maryland: Launching Work on Voice and Speech Intonation

After a decade as a postdoc and scientist at House, it was time to move back to a university. The Hearing and Speech Sciences Department (see hesp.umd.edu) at the University of Maryland (UMD), College Park, was to be my next home for a while. As I built the laboratory at UMD, serendipity again changed the course of my career. Shu-Chen Peng (now at the United States Food and Drug Administration [FDA]) joined our group as a postdoctoral fellow. She had a background in linguistics/speech language pathology and had completed her PhD at the University of Iowa, Iowa City, focusing on the perception and production of prosody by cochlear implant patients. Prosody refers to the tone and manner of speaking that conveys information beyond words, e.g., question/statement contrasts or emotion Acoustically speaking, voice pitch and its inflections constitute a primary cue to prosody. Until Shu-Chen's arrival in my laboratory, prosody was of peripheral interest in our laboratory, but this was to change quickly.

Our laboratory had been working on psychophysical studies of voice pitch coding in cochlear implants by measuring the patients' ability to detect and discriminate amplitude-modulated electrical pulse trains. Although normally hearing people are very sensitive to the harmonic structure of voices, cochlear implant patients do not have the same access to the harmonic structure and generally access a weak form of voice pitch from periodicity cues in the amplitude-modulated electrical pulse trains. At that time, this was generally thought to be the case, but there had been no demonstration that amplitude-modulation sensitivity was related to voice perception in cochlear implant patients.

To explore this issue, Shu-Chen designed her own experiments to quantify how cochlear implant patients used voice pitch and other covarying cues to tell questions (rising pitch) apart from statements (falling or flat pitch), using methods that were more rigorous than those she had used before. My studies of amplitude modulation and Shu-Chen's studies of question/statement perception were planned as independent experiments, but a serendipitous discovery changed this.

One day while going over results from Shu-Chen's experiments, I realized that the patients who were having trouble in my psychophysical measures were also the ones having trouble in her speech prosody perception tasks. As a psychophysicist, I had never really expected to find such clear relationships between discrimination measures on single electrodes and speech perception measures from broadband acoustic stimulation. I was truly excited. This led to a collaborative study in which we showed that amplitude modulation sensitivity in cochlear implant patients predicted their utilization of voice pitch cues in speech prosody. Our laboratory became more focused on speech prosody from that point onward.

Work at Maryland: Launching Pediatric Research

Being in a Hearing and Speech Sciences Department meant that my students and postdocs were more interested in translational speech perception studies than in the more basic psychophysics, and this influenced the direction of my research. An early audiology student in our laboratory was interested in speech perception by children with cochlear implants and persuaded me to set up a study for her research project involving children. This small study actually got our laboratory ready to work with children.

As it happened, there was another reason for our laboratory's growing interest in the pediatric population: if we could develop expertise in working with children, we could study the effects of plasticity in children who were congenitally deaf, received cochlear implants within the first year or two of birth, and whose auditory systems were developing with cochlear implants.

I was also becoming interested in how linguistic input might change pitch sensitivity in children who spoke tonal versus nontonal languages. In tonal languages, such as Mandarin, a word can change its meaning based on voice pitch inflections, so hearing these "lexical tones" is crucial for speech. Might children who were immersed in a tonal language and had been implanted early enough to benefit from the greater plasticity of the brain to overcome some of the device limitations in pitch perception? We wanted to ask exciting questions about how developmental plasticity, sensory deprivation, and prosthetic stimulation interacted to shape specific aspects of speech communication in children with cochlear implants. Shu-Chen, who was originally from Taiwan and was now working at the FDA, helped mediate a collaboration with Yung Song Lin's laboratory in Tainan, Taiwan. They were excited about our research questions and happy to work with us. Another student in my laboratory was interested in studying how children with cochlear implants perceived vocal emotions because voice pitch inflections are crucial for spoken emotion identification.

An obstacle presented itself now, in the form of funding. Our primary funding (my R01 grant from the National Institutes of Health [NIH]) was related to psychophysical and speech perception measures in adults with cochlear implants. To pursue work with children, we needed funding; to obtain NIH funding, we needed compelling preliminary data.

Serendipitously, unfortunate events outside our laboratory led us to funding for our work. The United States economy crashed in 2008; the American Recovery and Reinvestment Act legislation passed by the government in response allowed NIH to issue funding for grants that accelerated science. I seized the opportunity to propose an expansion of our laboratory's repertoire to conduct research on psychoacoustic and speech perception studies in children with cochlear implants relating to voice pitch coding and prosodic cue perception.

Fortunately, we were awarded a small two-year grant, which paid for Mickael Deroche's postdoc in our laboratory. Mickael (now at Concordia University, Montreal, Quebec, Canada) led our first psychoacoustic studies investigating fundamental frequency coding in children with cochlear implants. Serendipity had led us to funding that launched our pediatric research program in a serious way. The data collected under that grant formed the basis for larger grants from the NIH. We were able to establish a decade-long collaboration with Lin's laboratory in Taiwan and with Charles Limb's laboratory at The Johns Hopkins University, Baltimore, Maryland, and later at the University of California, San Francisco. We were able to answer key questions about voice pitch coding by pediatric cochlear implant recipients speaking Mandarin, comparing them to those in the United States speaking English. Soon, our studies on vocal emotion perception also started taking off.

Move to Boys Town

After eight years at the University of Maryland, I moved to Boys Town National Research Hospital (BTNRH) in Omaha, Nebraska, and established my third laboratory here. This came about through a string of serendipitous events.

First, Michael Gorga (a pioneering scientist at BTNRH) was invited to give a talk at Maryland, and we got to know each other during that visit. Next, one of the people on Walt Jestead's team (Walt was the Director of Research at BTNRH) applied for a postdoctoral position in my laboratory, but I didn't have funds to support her, and Walt mentioned that a simpler solution might be for me to move to BTNRH, implying that a position there was available if I was ever interested. I had never thought of moving to the Midwest. I responded politely, indicating that I was quite happy at Maryland for the moment. Over time, however, my workload (teaching alongside ever-expanding research commitments) at Maryland started increasing beyond my capacity, the laboratory expanded beyond the space available, and I felt that continuing to be productive on my grants was becoming challenging.

Suddenly, the thought of a job where I could simply focus on my research and interact with some of the greatest minds in our field on a daily basis became a luminous possibility. I asked Walt if the position he had mentioned was still open. It took another year and a half for me to wrap up things at Maryland and move to BTNRH, but I know that Walt and Michael played a key role in making it all happen. Again, if Michael had not visited Maryland and if that individual on Walt's team hadn't applied for a postdoc in my laboratory, perhaps the move to BTNRH would not have come about.

Aging Studies

My laboratory was studying the pediatric population more and more, and BTNRH had deep expertise in working with children. Our work with voice pitch and emotion perception was continuing, but we focused on the pediatric population, with typically hearing children and a group of typically hearing adults who were younger than 35 years of age as controls.

One day, I was looking at the data and was surprised to see one normally hearing adult scoring poorly in our emotion identification task. Digging deeper, I realized that a mistake had been made; that particular adult was 62 years old, not younger than 35 as our protocol required. Looking further, I realized that there was an established literature showing age-related decline in emotional prosody identification in adults with good hearing. This literature was sparse, however, and other than one or two studies, it wasn't clear that audiometric controls had always been carefully made. Discovering that serendipitous error led us to a number of studies investigating the effects of age, hearing loss, and cochlear implantation on spoken emotion perception by adults.

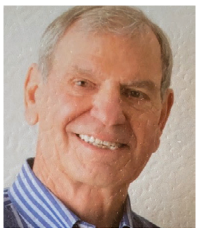
This area of research is now expanding in our laboratory, but soon we will need to secure external funding. I know the pattern by now. Something serendipitous will happen, lines will converge, and exciting things will ensue that I never planned for and didn't imagine. I just must allow the "out of the box" elements their space and time, and the last thing I should do is try to plan and control the path of my work.

Contact Information

Monita Chatterjee
monita.chatterjee@boystown.org
Boys Town National Research Hospital
Omaha, Nebraska 68010, USA

A Life Unplanned

Lawrence Crum



When Art Popper called me and asked if I could write a 1,500-word article on serendipity, I said "Are you kidding me, my life has been an experience in Serendipity—I can write a book!" I don't want a book, he said, and not about your life but about how it influenced your career in acoustics. With some reflection, I found several events in my life that greatly influenced what I wanted to do. These serendipitous events were instrumental in what I did as a career and who I am as an individual.

I did most of my undergraduate studies at the United States Naval Academy in Annapolis, Maryland. Unfortunately, after three years there, for personal reasons, I had to resign. At the Naval Academy, at that time, there were no majors or advanced degrees. We were training to become warriors and so we were given a broad education that prepared us for a career in the military.

However, for those of us who had good grades, we were allowed to take an "overload," that is, any course being taught at the Academy in addition to our regular course load that already was on the order of 20 (or more) semester credit hours. Of course, because there were no majors, the only way we could take an overload was to arrange something with an individual faculty member. I was a good student, especially in my history class, so I asked my history professor if he would teach me an extra class. He said he was a specialist in Russian history, and so I took a course from him in that field. I was so interested in that course and did so well that he suggested I take TWO overload classes. He said that he was the Academy's advisor for the Fulbright program, and if I did as he suggested, I could probably win a Fulbright fellowship after graduation, so I took several (tutorial) courses from him.

After three years, I transferred to Ohio University, Athens, which was near home. But as a result of my three years at the Naval Academy, I had enough course hours to graduate from Ohio University once enrolled. (By the way, I actually earned a Fulbright, but later on as a Faculty Fellow.) However, when my Ohio University advisor saw my transcript, he said that it would probably take me at least two years to fulfill the requirements for a major in history. Perplexed, I asked him if there was a field for which I could get a degree in the minimum amount of time. He saw that I had several courses in mathematics, and if I took 16 semester hours of math that summer, I could get a BA in mathematics. So, I did and graduated at the end of the summer; then I looked for a job. However, no one wanted to hire me with a math BA, and I couldn't teach, as I didn't have the education requirements. Quite dismayed, I went by the Physics Department and asked the department chair if I could take a few physics courses to improve my hire ability. Remarkably for me, he said that with a math degree I could go directly to graduate school in physics and that he would give me a teaching fellowship that not only paid my tuition but also covered living expenses as well. Serendipity: that's why I'm a scientist rather than a historian.

It was difficult to learn graduate level physics with only one undergraduate course, but soon I caught up and then it was time to find a theses advisor. Again, with "Time being of the essence." I was married and already had one child and another on the way. At the end of my second year, I went to each faculty member and asked which of them could ensure that I could graduate within another

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two years. In those days, nuclear physics was hot (remember Oppenheimer) so I wanted to work in nuclear physics, but I would have to wait at least two years to start my research. Frustrated, I talked with Physics Professor Burt Stumpf, who had no students, probably because he was working in the engineering field of acoustics. Happily, Burt told me that he had just received a new three-year Office of Naval Research grant to study the interaction between sonar transducers and I could start tomorrow. Serendipity: that's why I'm an acoustician.

Burt Stumpf was one of the finest university members that I have ever met. He took a personal interest not only in my education but also in my life. He was not a well-known scholar, although he was an Acoustical Society of America (ASA) Fellow. He was a devoted member of the ASA and insisted that I become a member of ASA as soon as I was his graduate student (that was in 1965, so soon I will be celebrating my 60th anniversary with the ASA). Burt made me go to every ASA meeting; his grant reimbursed me for my expenses, and he strongly recommended that at the meetings of the ASA, I present a paper on my ongoing research.

I found the ASA a remarkably welcoming place and gained many friends and associations as a graduate student. With Burt's expert guidance, I defended my dissertation after two years and started looking for a postdoc. Burt said that I should work with someone with a strong reputation in acoustics and gave me the names of those who were eminent at that time. Furthermore, during my fourth year in graduate school, Burt made me give a short briefing on each of the major physical acousticians of the day and what their specialties were. Thus, when I started looking for a postdoc advisor, I knew all those who were the major players in physical acoustics in the United States. So I wrote letters to nearly all of those well-known professors, and I had replies from nearly every one of them, maybe because they saw me at ASA meetings and even attended my papers. Serendipity: Ted Hunt at Harvard University, Cambridge, Massachusetts, one of the most respected acousticians in the United States invited me into his laboratory, and consequently, I was immediately accepted as one of his "students," an honor that helped me gain recognition in the ASA.

At the Naval Academy, every midshipman had to be involved in a sport. Since I really liked soccer, I tried out for the plebe (freshman) team, and at the end of the year, the soccer coach told me that I had made the plebe team, but I would play only sparingly. Another requirement for midshipman was to learn something about every one of the 24 NCAA sports at the Academy. Fortunately for me, when I met the fencing coach, he convinced me that I could not only be on the plebe team, but I could participate in nearly every match. There wasn't a lot of interest in fencing at the Academy. Serendipity: not only did I make the varsity team, but I won the NCAA National Championship in three years and was a member of the 1964 Olympic Squad, but not the team, which meant that I could not go to the Olympics as a competitor. However, it also directed me to my first real job.

After I finished my postdoc at Harvard in 1968, I started looking for a position as a faculty member at a university. There were a few good offers, but I still dreamed of making the Olympics and so I accepted a position on the physics faculty of the Naval Academy. This was a great job. I taught motivated students sophomore physics twice a week and spent lots of time playing golf, working out with the fencing team, and having a position (unpaid) as assistant fencing coach. Unfortunately, there were too many responsibilities as a new faculty member and by the demands of my family, so I never made any real effort to try out for the team.

A few years after I joined the faculty at the Naval Academy, the Office of Naval Research (ONR) announced that one member of the Academy would be awarded a large grant and become an ONR Research Professor for a year. Fortunately, I won the competition and had a full year with no teaching responsibilities and could concentrate on my research. I was interested in acoustic cavitation, and with my grant money, I organized a symposium on the topic. Among the attendees was a renowned cavitation expert, Terry Coakley of the University of Wales in Cardiff. We hit it off so well, he invited me to visit him and collaborate on cavitation research in tissue. I was due for a sabbatical, so in 1987, I took my family to live in the United Kingdom for a year. What a year that was! With no demands on my time, we bought a Volkswagen camper and put over 20,000 miles on it driving through all of the United Kingdom and Europe. And I was able to do enough research to write 11 journal articles on various topics that year. That serendipitous event greatly affected my entire life as I focused my research on international collaborations and was lucky enough to spend much of my career traveling around the world to organize meetings and collaborate with colleagues. Indeed, one of my most notable achievements was to make lifetime Diamond status on the Delta Airlines frequent flyer program, accumulating nearly 4 million miles.

In 1988, having proved to myself that I could do research, I went to the University of Mississippi (Ole Miss) in Oxford, Mississippi. While there, physics faculty member and acoustician Hank Bass, a few others, and I formed what we called PARGUM, Physical Acoustics Research Group at the University of Mississippi. Now Ole Miss is mostly a football school and not known for its academics. Consequently, PARGUM stood out as a strong research group and attracted the attention of the chancellor (president). Furthermore, at that time, the head of the United States House of Representatives Appropriations Committee was our local representative to the United States Congress, Jamie Whitten. In addition, the head of the United States Senate Appropriations Committee was Mississippi's Senior Senator, John Stennis, and in those days, "earmarking" was considered good for the country. Serendipity: the chancellor convinced the Mississippi federal representatives to earmark (appropriate in the United States) a budget of approximately $20 million to create the National Center for Physical Acoustics (NCPA), and I eventually became its director.

While at Ole Miss, I collaborated with a brilliant colleague from Johns Hopkins University, Baltimore, Maryland, Andrea Prosperetti, who had written a highly cited article suggesting that the underwater noise produced by precipitation was a major component of the ambient noise in the ocean. One of my graduate students, Hugh Pumphrey, had discovered that raindrops generated an underwater bubble on impact and this bubble generated a significant component to ocean ambient noise in the kilohertz-frequency range. Andrea wondered if snowfall generated any significant noise and suggested we do some experiments. Of course, there is seldom snow in Mississippi; however, while visiting Bob Apfel at University, New Haven, Connecticut, a big snowstorm was predicted for the Washington, DC, area. Borrowing Bob's car and a couple of his graduate students, we loaded up his car with instruments and we went storm chasing. We caught up with the storm in Northern Virginia and convinced a Holiday Inn motel manager to let us use his swimming pool. While surrounded by hotel guests as we instrumented the pool, we obtained some very interesting data on the amazingly loud sounds produced by impacting snowflakes (Crum et al., 1999). In that experiment, performed in a motel swimming pool during a heavy snowstorm, we discovered that the ambient noise in the pool increased by over 30 dB in the hundreds of the kilohertz-frequency range. Our paper on the subject generated such general interest that Kenneth Chang wrote a full-page story on it in the *New York Times Science Times* and I was interviewed by Scott Simon on NPR. Serendipity: I was famous for 15 minutes.

After a few years as director of NCPA, I became interested in technology transfer and found .the investment community in Mississippi lacking. Accordingly, in 1992, I accepted a job in the Applied Physics Laboratory (APL) at the University of Washington. Seattle was and is a hot spot for startups, and I wanted to try my hand at founding some companies. While at the APL, I consulted for a small startup in Silicon Valley, California. When I was shown its technology, I became terribly interested in the area of medical acoustics. I saw a man being treated for BPH (benign prostatic hypertrophy). A device was inserted into the patient's rectum and this device imaged the prostate and then applied high-intensity focused ultrasound (HIFU) to denature the tissue around the urethra. When they applied the HIFU, there was a popping sound that I eventually described in a subsequent research paper as HIFU-induced "popcorn" (Crum, 1996). The ultrasound was applied at such an intensity that the tissue was superheated, and then when a nucleation site was initiated, the tissue exploded into a vapor bubble. This phenomenon, heating tissue until a vapor cavity is formed, which subsequently results in major disruption and lethal damage to the tissue, is now a major technology: Boiling Histotripsy. Serendipity: seeing HIFU-induced popcorn appearing in a human induced me to develop my principal area of research, therapeutic ultrasound.

For most of my career, I have been a researcher in acoustics, generating research proposals to whomever would accept them, and when funded, I made plans as far in advance as five years as to what we would discover. It hardly ever turned out that way. Many of the most important discoveries were unintended. Indeed, my life has been a lot like my research projects, planned, but as described above, few things went as I had hoped, but then serendipity happens, and things tend to work out for the best.

One of my favorite poets is Robert Burns (1786), who wrote:

"The best laid schemes o' Mice an' Men
Gang aft agley"

So, Art, you are right. Serendipity rules!

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Contact Information

Lawrence Crum
lacuw@uw.edu

Center for Industrial and Medical Ultrasound
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, Washington 98105, USA

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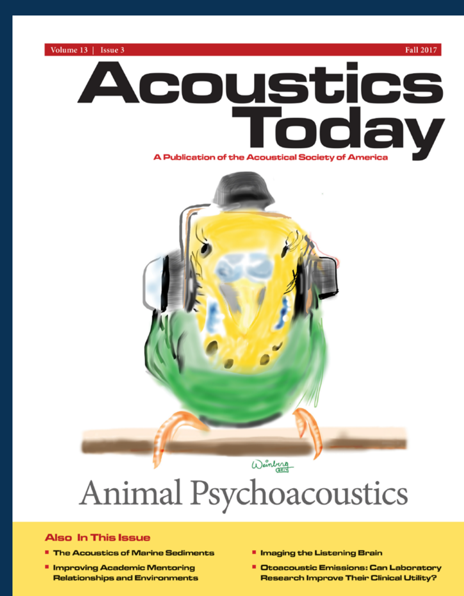

A Serendipitous Event Leading to a Career in Animal Bioacoustics

Micheal L. Dent

When I think about serendipitous events in my life, there are a few. My favorite noncareer happening was when my husband and I took my stepdaughter into the adoption agency we had been working with for years to drop off some cans for their food drive. When we serendipitously poked our heads in to see our adoption caseworker, she excitedly ushered us into her office saying she had just been about to call us. We got the privilege of hearing, in person and after two years with that agency, that we had been chosen by my daughter's birthmother to raise our (now) daughter just minutes after the caseworker had received the special news. Do not get me wrong, the announcement would have been fantastic on the phone as well; it was just extra exciting to be surrounded by all the people we had worked with for years to grow our family and feel the enthusiasm from the whole office. It was a joyful moment for everyone involved. I can easily list this serendipitous moment as one of the best moments of my life and something I will never forget.

But beyond serendipity in life in general, serendipitous events in my work life all arise from one serendipitous moment with one person, Robert J. Dooling (aka "Bob"; see bit.ly/3zCf4P0) from the University of Maryland, College Park (UMD). The saying "to know him is to love him" truly applies to this man who absolutely changed the course of my life in all the best ways. I owe him everything and often wonder what my life would be like had this initial serendipitous event never happened.

I was not someone who envisioned this career I find myself in, not even close. I chose my undergraduate institution, St. Mary's College of Maryland, St. Mary's City, because they had an excellent elementary education training program. When I got to St. Mary's, instead of the many human development courses, I found myself taking a lot of psychology classes because they fascinated me. In my sophomore year, I took "Sensation and Perception" as well as the "Psychology of Learning." The "Psychology of Learning" class had an attached laboratory where each student got their own rat. We used operant conditioning to train our rat to press a bar for a food pellet. We measured rates of acquisition, compared schedules of reinforcement, and tracked extinction. I absolutely loved it and was captivated by my little rat and its actions each week.

I was also taking "Sensation and Perception" that same semester. I had always been fascinated by the visual system and visual illusions. My father was working on his master's degree in education while I was a middle schooler, and I remember poring through his "Sensation and Perception" textbook with him, marveling at the old woman/young woman, duck/rabbit, vase/face figure-ground, after illusions, and Muller-Lyer illusions (for examples, see bit.ly/4cN1w1k). Learning about how our sensory systems work (and how they can be fooled) intrigued me like nothing had ever intrigued me before. I still feel like that kid when I encounter these illusions in the real world. The more recent blue dress/gold dress (see bit.ly/3WkPkj3) and Yanny/Laurel (see bit.ly/3zzOoy5) social media controversies are evidence that I am not alone in my curiosity about how our sensory systems operate.

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Needless to say, after my sophomore year of college, I no longer wanted to be an elementary school teacher. Unfortunately, there was only one animal laboratory at my small undergraduate institution, and in it, they studied the effects of various drugs on rat behaviors. I volunteered in that laboratory until I finished my degree, but the field never appealed to me like the sensory/perceptual discipline did. I did realize, however, that I wanted to enter the psychology research field. I did not, unfortunately, know how to go about this. So, I found myself wandering over to the college's notoriously underutilized Career Center. When I explained my changing interests to the career adviser, he suggested we call some local universities to see if any psychology research laboratories were in need of a research assistant.

This is where the serendipity came into play. At the time, Bob Dooling was the associate chair of the Psychology Department at UMD. Bob has never made it a habit of hanging out in the main office of the department, but for some reason, he was there that day working in his administrative role. He heard the message my career adviser was leaving on the voicemail and just happened to need a research assistant at the time. He took over the call, and we set up an interview for me in the coming weeks. I put on my new suit (yes, it was the first and last time I ever wore an actual suit), visited Bob's bird psychoacoustics laboratory, and landed the job that ultimately set me on my career path. If, serendipitously, Bob had not been in the Psychology Department office that day and taken that phone call, I do not know where I would be right now. It is highly unlikely that he would have received the message and called back.

I am still not sure why Bob took me on. I was pretty useless in the laboratory in the beginning, with little experience in computers, programming, electronics, experimental design, animal care or husbandry, or knowledge of the auditory system. The one thing I had going for me was a willingness to learn. I took on any project Bob proposed, eager to make myself indispensable. After two years in the laboratory as a research assistant, I was enjoying the research so much that I decided I wanted to pursue a PhD. Luckily, Bob continued to see my potential and accepted me into the PhD program in biological psychology at UMD.

I was a trainee in the Dooling laboratory for nine years total (two years as a research assistant and seven years as a graduate student). Yes, that is a ridiculously long time to be a trainee. I am aware that I just did not feel the need to rush out of there. I wanted to soak in as many experiences as I possibly could. Bob was the absolute best mentor, and we worked so well together. I remember many a human psychoacoustics seminar where he would lean over and say "let's try this in the birds to see what they do" or when he would introduce me to a collaborator and a new project would take off from there. This led to me getting to work on hair cell regeneration projects with Brenda Ryals from James Madison University, Harrisonburg, Virginia (see bit.ly/3S1XHxq), spatial unmasking projects with Ole Naesbye Larsen from the University of Southern Denmark, Odense (see bit.ly/4cYx44j), Schroeder-complex masking projects with Marjorie Leek from Loma Linda University, Loma Linda, California (see bit.ly/3WlKbqM), and a cochlear brainstem anatomy project with Catherine Carr at UMD (see bit.ly/4623w3E). The collaboration with Ole led to my attendance at the Odense University Summer School in Acoustic Communication, which was a fantastic field/classroom course that then serendipitously led to a six-month research fellowship at the Technical University of Munich, Munich, Germany, studying hearing in barn owls with Georg Klump (see bit.ly/461uFUk) when I found myself sitting next to Georg on a long bus ride to a field site.

I learned about the precedence effect, or the perception of a leading stimulus while suppressing an echo version of that stimulus, sitting next to Bob at a conference. For once, I leaned over to him and said, "Let's try this in the birds and see what they do." Here was my chance to dive into understanding one of those auditory illusions in an animal, and it ended up being the topic of my doctoral dissertation. We thought that since the birds we studied (budgerigars, canaries, and zebra finches) were terrible at sound localization that they might not experience the precedence effect, because timing cues, including binaural timing cues, were thought to play a role in the suppression of echoes by the auditory system. We turned out to be wrong; the timing of the precedence effect differed from what had been previously measured in other animals, but it was still present in the small birds.

Bob suggested that I reach out to Tom Yin at the University of Wisconsin-Madison (see bit.ly/3W4PAkz) for a postdoctoral position, and he gave me the best advice yet again, saying we would really hit it off and that I would have a great experience with Tom. I was not super enthused to potentially move to Madison, but Bob said to keep an open mind. Tom met me at the Madison airport in shorts and flip flops, took me for a beer and some popcorn at the Terrace at Memorial Union overlooking Lake Mendota, and we talked science for hours. Tom was another fantastic mentor that I feel lucky to know and to have worked with in my career.

So, Bob was absolutely right that Tom was a great match for my postdoctoral work. I was able to gain more experience and knowledge of animal models of hearing (and specifically spatial hearing), and I added animal physiology to my repertoire of techniques. While there, I learned to record from the inferior colliculus of awake cats while they were behaving in a spatial hearing task. I recorded suppression to "echoes" at various timepoints following initial sounds in precedence effect paradigms, and I studied another auditory illusion that had never been measured in an animal species, the Franssen effect. The Franssen effect is related to the precedence effect in that secondary sound sources are suppressed by the auditory system (see bit.ly/3LmZadW).

As fabulous as it was working with Tom and Dan Tollin at Wisconsin, the number one thing the work taught me was that cat behavior was NOT for me. The cats had attitudes like the birds never had. I still say that there is a reason people generally do not train their cats to do tricks. I knew that I wanted to return to measuring hearing by birds when I got a position in my own laboratory.

Even though I was out of Bob's laboratory for a few years by the time I went on the job market, Bob was also the one who helped me get my first (only) academic job. I serendipitously applied for a junior faculty position at the University at Buffalo-State University of New York (SUNY), Buffalo, New York, not thinking I had any connection to the place. However, just a few years earlier, Buffalo had tried to recruit Bob to be their Psychology Department Chair. They really wanted him, and he really wanted to go, but he had personal reasons for wanting to stay in Maryland. Bob reminded me of all this when I got the call to interview at Buffalo. He also reminded me that I not-so-politely declined moving with him as a graduate student were he to go, deeming Buffalo "too cold and snowy." I was a naïve youngster then, thinking academics could pick and choose easily where they wanted to live. The realities of the job market years later made me realize that you go where you can get a job, and I was thrilled when Buffalo had me in to interview. Every person I met in the Department during my interview week remembered Bob and was very fond of him. To this day, I think I got the job because I was "close enough." It also did not hurt that Richard Salvi was on the hiring committee and that he and Bob had been great friends for years.

Even my current academic collaborations have Bob Dooling connections. Bob knew I loved traveling and sent me to the International Conference on Neuroethology in Cambridge, England, as a graduate student. While there, I went out to dinner with a group of friends of friends that included Matthew Xu-Friedman. I remet Matthew at the new faculty orientation at Buffalo, where he reminded me of our dinner in England years earlier. Matthew, Dick Salvi, and I had regular lunches together during our first few years in Buffalo and started doing mouse psychoacoustics a few years later. We teamed up with Amanda Lauer, who was a graduate student in the Dooling laboratory toward the end of my time there, and Amanda and I have been trying to convince study sections of the importance of animal psychoacoustics ever since!

Bob also sent me to the Binaural Bash at Boston University, Boston, Massachusetts, one year where I was serendipitously assigned to stay with Barbara Shinn-Cunningham. A long conversation with her and David McAlpine about my precedence effect in the birds project helped me understand a lot of things I did not consider about the binaural system and complex hearing processes. To this day, Barb remains a great sounding board and consultant and is always readily available to offer advice when asked. I would put her in the same category as Bob and Tom when I think of supremely generous human beings eager to help others succeed.

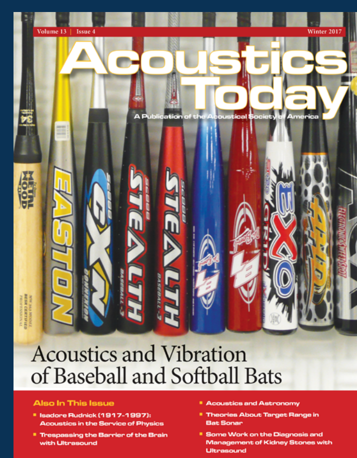
Finally, my serendipitous events leading to my connection with Bob also led me to my position as the associate editor of *Acoustics Today* (*AT*). Bob and Arthur Popper (editor of *AT*) were a famous twosome during my graduate school days, so, of course, I knew Art well and have always considered him a second mentor. He asked me to write an article for *AT* about animal psychoacoustics after I gave an Acoustical Society of America talk several years ago. I guess he decided that we worked well together and pitched me the position of associate editor of the magazine. I have learned so much from Art and I am certain I would not have been on his radar at all for such a job if he had not known me from my days as a graduate student in the Dooling laboratory.

In summary, I have no doubt that the intercepted call by Bob from my undergraduate career counselor was THE defining serendipitous event of my career. It led to many other serendipitous events that have helped me thrive as a scientist all these years. Working closely with and learning from someone so knowledgeable, respected, and giving continues to have been an effective strategy for my career as an animal bioacoustician to this day, over 30 years later. I still do not know why Bob was in the main office that day, four floors away from his laboratory where he was usually found, but I am grateful for the serendipitous nature of his wandering.

Contact Information

Micheal L. Dent
mdent@buffalo.edu

Department of Psychology
University at Buffalo
State University of New York (SUNY)
B76 Park Hall
Buffalo, New York 14260, USA



Serendipity in Acoustics: An Early Career Journey

Judy R. Dubno

Serendipity in science and throughout our professional careers and personal lives takes many forms and occurs regularly. The most vivid examples are the random connections created as we, by apparent accident, meet potential research collaborators where we work, at scientific conferences, or even at family gatherings. We have learned to be open to these rare opportunities and see them as occasions for moving in new directions, developing new ideas or skills, or simply making new friends. Many of us missed these chance occurrences during the pandemic when travel and personal interactions were limited, and as a result, we have recognized their importance to our careers and to advancing science. Therefore, this is an excellent time to consider the meaning and significance of serendipity as we return to interact with the world again.

For me, the most valued and essential serendipitous event occurred very early in my scientific career, at the time when I was advancing from a master's-level education and a brief clinical experience in audiology to becoming a PhD student with a goal to study auditory sciences. In the mid-1970s, I was admitted to the PhD Program in Speech and Hearing Sciences at the City University of New York (CUNY) Graduate School and University Center where I would begin my doctoral education.

At that time, my knowledge of research topics or mentors available in the CUNY PhD program was limited, so I set about to learn the opportunities available for a new PhD student and graduate research assistant. Readers should keep in mind that this time (the mid-1970s) was before the Internet and electronic communication, so learning about PhD programs meant visiting a university library to review the academic catalog, which described the program of study, faculty, course offerings, and the requirements leading to the PhD. While at the university library, I also spent time reading scientific publications (including many from *The Journal of the Acoustical Society of America*) to become familiar with the research being conducted by CUNY faculty in auditory sciences. Armed with this information, I felt prepared to discuss potential options for research projects with one of CUNY's leading auditory scientists and a potential mentor, Harry Levitt (see bit.ly/4fjCglp). I received a letter (a paper letter in the United States mail) from the PhD Program's Executive Officer, Irv Hochberg, stating that several PhD program faculty members would be contacting me by telephone in the following few weeks to discuss my responsibilities as a graduate research assistant and describe ongoing research in the department.

After several visits to the university library, I was thoroughly prepared to carefully consider the various options and make this very critical decision at some future date. But I was surprised to learn when Harry Levitt called me the day after I received Hochberg's letter and let me know he needed my decision immediately! He then described four research projects he was directing and explained their goals and how I would contribute to each as a graduate research assistant. With that minimal information, limited knowledge of hearing aids from my brief clinical experience, and some very kind encouragement from Harry, I

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selected one, which Harry called the "wearable master hearing aid" (WMHA) project. From Harry's description, the project seemed quite straightforward. What I did not know at the time was that my decision would lead to Harry becoming my major advisor and chair of my doctoral committee and that the WMHA project and related subprojects would become a major focus of my scientific career for a decade or more. That telephone call with Harry was certainly a serendipitous moment.

Some months later when I entered the CUNY PhD program, I joined an incredible team of researchers working on the WMHA project, a National Institutes of Health (NIH)-funded program. The overall goal was to develop and evaluate methods for the automated selection of hearing aid specifications using the WMHA, one of the first in the analog era, using an early form of a multivariate adaptive testing strategy. During the experiment, tiny electronic modules would be inserted using tweezers into the WMHA (about the size of today's mobile phones) by the examiner (me) to modify the hearing aid's lower frequency cutoff and frequency-gain slope. Then, the combination of cutoff frequency and slope settings yielding the highest speech recognition score would be determined.

This assessment required a very sensitive measure of speech recognition, which did not yet exist. Consequently, during my first year or so on the WMHA project, I was heavily involved in the development, recording, and analysis of the CUNY Nonsense Syllable Test, which was among the first syllable tests that generated a matrix of consonant errors (from paper and pencil responses) and is still in use today (Dubno et al., 1982). I subsequently used that test as the basis for my dissertation research, which involved predicting consonant confusions by individuals with normal and impaired hearing from acoustic analyses of consonants (Dubno and Levitt, 1981).

In addition to developing speech-recognition materials and collecting and analyzing data, I assisted Harry in the preparation of NIH progress reports and presentations and agendas for the quarterly site visits from our NIH Program Officer (Lois Elliott, later Earleen Elkins); progress reports and site visits were quarterly because the project was supported by an NIH contract, an important distinction from an NIH grant. From these challenging experiences as a PhD student, I gained an early education from Harry, Lois, and Earleen about NIH-funded research and developing contract and grant proposals, which in future years helped me fund not only my own research but in advising others about supporting their research.

Looking back on my serendipitous beginning as a CUNY PhD student with Harry as my major advisor, I can honestly say that nearly everything important I know about auditory research I first learned from Harry. He didn't only teach me facts, but he taught me how to learn, how to think, and, most important, how to think like a scientist. At the CUNY Graduate School, he worked on research related to binaural hearing, sensory aids, analysis of the speech of individuals with communication disorders - especially deafness, experimental audiology, and auditory psychophysics. Harry is best known for the development and use of digital and computer-assisted technology by persons with communication disorders. These include computer-assisted adaptive testing in auditory psychophysics, computer simulation of speech, computer analysis of syntax and other language skills of deaf children, analysis of visual cues in speech intelligibility using video processing of faces, digital hearing aids, noise reduction devices in hearing aids, and the WMHA. His research at CUNY developed methods to predict speech intelligibility and enhanced psychophysical procedures, especially adaptive procedures. Indeed, one paper published in 1971 (Levitt, 1971) reporting on an adaptive procedure of the transformed, up-down type has become the second most cited paper in the history of *The Journal of the Acoustical Society of America* (source: Crossref API).

In keeping with the theme of this special issue of *Acoustics Today*, I tried to recall other serendipitous events that led me from CUNY to UCLA to my current faculty position at the Medical University of South Carolina, Charleston. Those transitions in location occurred because I became connected to people who offered postdoctoral fellow and faculty appointments that led to outstanding mentors and scientific colleagues. The ongoing expansions of my research focus through lifelong learning occurred because I was connected to people who became collaborators, mentees, and trusted advisors at all career levels, and those connections led to others, and so on. The initial sparks came about through seemingly mundane meetings or telephone/email exchanges. Looking back, I am not sure that these connections were truly serendipitous, but they had the characteristics of serendipity. That is, they occurred by being ready and willing to take chances on unique opportunities to explore new research directions, to accept new leadership roles when offered, and generally to say “Yes.”

In closing my tale of Harry’s serendipitous telephone call and my early-career journey, I would like to relate a “degrees-of-separation” story that Harry told me about Albert Einstein. One of Harry’s professors at Imperial College in London was Dennis Gabor (see bit.ly/4c8thQZ), who invented the hologram among many other contributions, for which he received the Nobel Prize in Physics in 1971. Despite his fame, he was most proud that he had been a student of Einstein’s. Harry then told me that I could be proud that I was a student of a professor (Harry) who was a student of a professor (Gabor) who was a student of Einstein. And Harry said I should tell my students that they should be proud, too, of their link to Einstein. But, instead, I tell them they should be proud to be students of a professor (me) who was a student of Harry Levitt. That’s serendipity!

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Contact Information

Judy R. Dubno
dubnojr@musc.edu

Department of Otolaryngology-Head and Neck Surgery
Medical University of South Carolina
135 Rutledge Avenue, MSC 550
Charleston, South Carolina 29425-5500, USA

In Life, Like Underwater Acoustics, Paths Are Seldom Straight

Marcia J. Isakson

Serendipity reveals itself in those small interactions or events that change the course of your life. In chaos theory, small changes in initial conditions cause large changes in the final state of the system. This was famously described as the flap of a butterfly's wing in Brazil causing a tornado in Texas (Lorenz, 1993). To me, serendipity is the butterfly's wing.

Growing up in Hereford, a small cow town in the Texas panhandle, I may have needed more serendipity than most to get to where I am today. The first time that serendipity stepped in to reveal my next step, it influenced my choice of college. When I was in high school, we moved from Hereford to Chicago and then to Connecticut. On our way to Connecticut, we stopped by the United States Military Academy at West Point to take a tour of the historic campus. While on the tour bus, my mom remarked about how I should consider attending, especially since the campus was so beautiful. However, I had no plans to apply. The tour guide interrupted, stating I would not get in since West Point was very selective. Well, I found that exceptionally annoying, so I made it a point to apply. Long story short, I started as a new cadet in 1988.

Going to West Point had a tremendous impact on my life. None of my family had been in the military. Being in the army gave me a passion for national security. I learned to deeply respect the sacrifices that our service men and women make every day to keep the world safe. However, being in the military did not quell my passion for science and math that I have had from a very young age. I pursued degrees in both physics and mathematics at West Point. In my junior year, I experienced my second brush with serendipity. I was asked to spend a semester at Brookhaven National Laboratories, the first cadet ever to do so.

Being at Brookhaven showed me the world of academic research. I was involved with a nuclear engineering project and published my first paper (Tuyle et al., 1993). Based on that experience, the academy asked if I would apply for a Hertz Foundation Fellowship. Major John Robertson, a West Point physics professor, helped me prepare for the rigorous two-round interview. Without such a fellowship, I would not be able to attend graduate school after West Point. Instead, I would be assigned to an operational unit like the rest of my classmates. However, again, serendipity intervened, and I was awarded a Hertz Foundation Fellowship in 1992 for the study of physics, thus, once more, changing the entire trajectory of my life.

I attended the University of Texas (UT) at Austin for my master's degree to be close to Fort Cavazos where my husband, John Isakson, was stationed. After completing that degree, I served first as a shop officer and then as a battalion operations officer in the 544th Maintenance Battalion. As a shop officer, I was responsible for ensuring direct support maintenance to army units. The soldiers in my shop fixed everything from tanks to small arms to radios. As a battalion operations officer, I was in charge of defense tactics, movement planning, qualification compliance, and intelligence for a 900-soldier maintenance battalion. I had a staff of 18 officers and noncommissioned officers (NCOs). I was happy in the army, serving the national security mission, but I knew I needed to

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get back to physics and math. So, in 1997, I resigned my commission to return to graduate school at UT Austin.

The second time through graduate school was challenging as I had two babies, both of whom were born prematurely. My husband and I worked as a team to raise our young family, and in 2001, I was anticipating graduating with my PhD in physics. I truly had no idea what I was going to do next, but again, serendipity intervened. My advisor, Dr. Greg Sitz, casually mentioned that there was a defense laboratory, Applied Research Laboratories, at UT Austin (ARL:UT; see arlut.utexas.edu). This sounded great since I was interested in both national security and physics. I dropped off a resume at a career fair, without even talking to anyone. A week later, I was interviewed by Dr. Nick Chotiros, a long-time member of the Acoustical Society of America (ASA), for a job researching underwater acoustics. I had never worked in acoustics but had a long history with lasers and electromagnetic (EM) radiation. Nick told me "It's the same wave equation. You'll be fine." (It's not.) I started at ARL:UT in 2001, about a year before I finished my PhD.

I truly enjoyed my career at ARL:UT. I eventually learned the acoustic wave equation and taught underwater acoustics on the graduate level for years. I became interested in acoustic propagation in shallow water waveguides and scattering. I went on 15 at-sea tests. I loved the complex math and working with experimental equipment. I would spend hours honing a finite-element model or constructing a transducer interface. I thought that I would spend the rest of my career in research since I loved it so much. However, just as I was getting comfortable, serendipity nudged me once again.

It started with the ASA asking if I would consider running for president. I was on the Executive Council and had also served as the chair of several committees including External Affairs, Women in Acoustics, and Publishing Services. I had also served as the ASA representative to the American Institute of Physics. However, I was so sure that I would not be elected that I did not even mention that I was running for president to my laboratory director at ARL:UT. I was as shocked as anyone when I was elected to serve from 2017 to 2018. As the president, I realized that I might have some potential as a decent manager.

Then in 2018, the ARL:UT executive director, Dr. Clark Penrod, retired. One of the technical laboratory directors, Dr. Karl Fisher, took on that role, leaving a technical laboratory director job open for the Signal and Information Sciences Laboratory (SISL; see bit.ly/3XQNBTL). Walking by that director's office one day, I ran into a long-time colleague of mine in SISL. I mentioned that they would be soon getting a new director. He asked me if I would apply. I hadn't even considered it before that moment, but his casual (and serendipitous) comment stuck in my mind. After a few weeks of consideration, I decided to apply.

Although I was not chosen for the directorship, Karl asked me if I would take on some management duties including coordinating the ARL:UT Internal Research and Development (IR&D) program, running the laboratory-wide Task Force Ocean (TFO) project (see tinyurl.com/2febmb63) and interfacing with the newly stood-up Army Futures Command (AFC; see army.mil/futures) in Austin.

These new roles changed my career substantially. I went from a mostly independent researcher with a few students to coordinating dozens of IR&Ds, managing the TFO program with 25+ researchers, and establishing a new relationship for the laboratory with the army, all from the serendipitous moment of a casual question in the hall by a coworker.

Because of the IR&D program, I learned about research going on throughout the laboratory, broadening my perspective. Through the TFO community, I was invited to serve on the National Academies Ocean Studies Board and two National Academies study committees (bit.ly/3xN1702). From the AFC relationship, the laboratory established multiple new programs worth millions of dollars. Then, in 2021, the SISL director retired. I applied again and was hired as laboratory director.

Today, I still serve as the SISL Laboratory Director, a position I never imagined myself in, even six short years ago when I was confident that I would be researching underwater acoustics for the rest of my life. One of those premature babies, Grace (Isakson) Murley, is married and halfway through her MD/PhD at the University of Texas McGovern Medical School working in imaging with MD Anderson. She already has three publications.

The other premature baby, Nicholas Isakson, now works for a major defense contractor in Dallas, Texas, as a software engineer, following in his mom's footsteps in national security. I can't wait to see where serendipity will point these wonderful young adults.

As for myself, although I always knew I wanted a career in math and science, I had no idea how that would develop. Like ray paths in underwater acoustics, the path of my life was seldom straight. I could not have predicted my career trajectory. I have no idea where serendipity will steer me next, but whatever it is, I'll be ready to face it.

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Contact Information

Marcia J. Isakson
misakson@arlut.utexas.edu

Applied Research Laboratories
The University of Texas at Austin
10000 Burnet Road
Austin, Texas 78758, USA

What a Wonderful Wave

Nicole Kessissoglou

Nicole Kessissoglou and Steffen Marburg in Manchester, UK, in June 2023; personal photo, used with permission.

I have been fortunate to have experienced a number of serendipitous events that ignited (and reignited) my passion for waves in structures and sound fields. The first event was undoubtedly the most important because it kick-started my research journey. I was a PhD student in mechanical engineering at the University of Western Australia, Perth. At the time, I was already many months into my PhD and rather lost (although this was not the fault of my wonderful supervisor). I knew that I wanted to pursue a PhD on active vibration control; however, I was not thinking expansively and as such, had not considered structures beyond simple beams or plates. Unfortunately for myself, active control was the flavor of the 1980s and 1990s and the year was already 1994. I was starting to feel despondent that I was too late to the topic and not up to the task of doing a PhD.

Let me digress with two important factors leading to my fortuitous event. The first is that I had commenced my PhD in the days when journals were only available in hard copy. The second is that the department included a strong academic group on structural vibration. The group was led by the late Michael Norton (whose excellent book on noise and vibration I still use for teaching and research), Brian Stone (whose enthusiastic teaching on spring-mass-damper systems using only chalk and a blackboard was truly inspirational), and, of course, my supervisor, Jie Pan (who recently told me he is now the oldest professor in the department!). Needless to say, there were quite a number of PhD students being supervised by these academics. So, to this day I don't know who left a discarded page in the photocopy room on Eric Ungar's (1961) article in *The Journal of the Acoustical Society of America* (*JASA*). After a few moments perusing the page, I experienced a eureka moment, I would study active vibration control of *beam-stiffened plates*!

But my luck didn't stop there. I acquired the full paper and fell in love with the approach that Ungar took in modeling a symmetrically reinforced beam-stiffened plate as three subsystems in the direction of wave propagation, namely, plate 1, beam, and plate 2. Ungar showed that by considering the coupling between different wave types at the boundary interfaces of the beam and plates, maximum energy transmission through the beam occurred at optimal wave-matching conditions between flexural waves in the plate and flexural waves in the beam (termed flexural coincidence), and at optimal wave-matching conditions between the plate flexural waves and torsional waves in the beam (torsional coincidence). This detailed understanding of the wave propagation and transmission shaped my philosophy and approach toward research problems that I have upheld throughout my entire career. I was then able to tailor the design of the active control system to target only those transmitted waves (okay I confess, it was probably my supervisor who designed the active control system). This work led to my first journal paper that was published in *JASA* (Kessissoglou and Pan, 1997). Seeing the printed paper in the university library was one of the happiest moments of my life. I felt immortalized!

Fast forward two decades from my lucky discovery in the photocopy room, at which stage I was an associate professor at UNSW Sydney. I hadn't made active control a career focus and as it turns out, I still wasn't thinking expansively. As far as I was concerned, active (or passive) noise and vibration control was a technique to attenuate the *total* acoustic or vibrational field. That was all about to change.

In 2015, I was invited to give a talk at an Australasian conference called KOZWaves (K for Kiwi is a nickname for a New Zealander and OZ for Aussie is a nickname for an

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Australian). It was a small, intimate conference devoted to all branches of wave science. This conference wasn't on my radar, and I didn't anticipate getting much out of it (and furthermore, I was only able to attend two out of the three days). I had unwittingly become stuck in a routine of attending the same large annual conferences primarily focused on acoustics and vibration and typically attended by researchers in mechanical engineering. KOZWaves turned out to be a refreshing experience in which I met a range of researchers from physics and mathematics as well as from engineering, all with a common interest in waves.

During KOZWaves, I was listening to a talk from an applied mathematician, William Parnell, on the topic of active cloaking of elastodynamic systems (Norris et al., 2014). Although admittedly I couldn't follow most of the math, his talk provided another eureka moment. Can we use active control to cancel a specific wave component? I was once again excited by active control of waves. My first attempt was to cancel a wave component of the displacement field in a finite structure. This turned out to be more challenging than anticipated, so attention was turned to active manipulation of sound scattering and radiation from structures in acoustic domains of infinite extent. A literature survey soon revealed that similar acoustic cloaking using active control had been introduced by Jordan Cheer (Cheer, 2016). However, it was the first time I had considered the possibility of manipulating waves in extraordinary ways, which, in turn, led to a fervor when I discovered acoustic metamaterials.

Throughout 2015 and 2016, I was mentioning my keen interest in acoustic metamaterials to anyone and everyone. I was quite obsessed! In June 2016, I successfully gatecrashed a metamaterials workshop in Edinburgh, Scotland, that was being hosted by William Parnell. Similar to KOZWaves, it was a fantastic, small, intimate conference from which I learned a lot (mostly that once again, I was late to the topic). Somewhere along the way, I must have mentioned my interest in metamaterials to my colleague, Alex Skvortsov, who is based in Melbourne, Australia, and whom I kept bumping into at conferences (including KOZWaves). Alex was equally keen on metamaterials, and we agreed to recruit a PhD student to the topic. Our mutual interest and shared philosophy on an in-depth understanding of wave phenomena became the catalyst for our beautiful work on wave scattering in locally resonant soft coatings. Come full circle nearly 10 years later, William Parnell and I are currently collaborating on cloaking, and Alex Skvortsov, William Parnell, and I are currently collaborating on subwavelength resonance of inclusions in a soft material.

There have, of course, been numerous other important serendipitous events, notably chance encounters with colleagues earlier in my academic career who became long-term collaborators and lifelong friends. I joined UNSW in 2003 and a couple of months later, I met Roger Kinns, who was visiting another academic at UNSW. We bonded over my casual mention of Cambridge University, Cambridge, United Kingdom (I was about to spend a couple of months there and was terribly excited). As it turned out, Roger is a Cambridge graduate, and he provided me with lots of useful information and contacts. Our continued enthusiastic conversations on Cambridge led to Roger becoming a collaborator for many years and cosupervisor of my PhD students. I met Steffen Marburg (see photo) at a conference in France in 2005. Steffen was quite obsessed with Australia at the time, and there were not many Australians at the conference. On hearing my Aussie accent one lunchtime, he cornered me and insisted on visiting to identify a collaborative project (and we are still collaborating) (see my photo).

I feel very fortunate to have worked with many wonderful and generous people on waves in structures, fluids, and soft materials. But it was Ungar's paper (1961) that provided the serendipitous spark for waves that is still burning. To the person who left Ungar's work in the photocopier room, I am forever grateful.

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Contact Information

Nicole Kessissoglou
n.kessissoglou@unsw.edu.au

School of Mechanical and Manufacturing Engineering
UNSW Sydney, New South Wales 2052, Australia

A Serendipitous Spiral Path to a Career in Hearing

Darlene R. Ketten

A Package in the Mail

The package weighed about 25 pounds. I knew it was coming, and it was like so many that I received or sent in the following decades, but this was the first. Far bigger than I expected, the size doubled the excitement. Opening the box, I found an intimidatingly large, heavy cube of bone, quite solid, ivory colored, and with an odor that was not repellent but with a mustiness that made clear it was the real thing, a chunk of a mammalian skull that promised to hold an "ear." The specimen had been sent by William (Bill) Watkins, who had been gracious enough to obtain it during his examination of a dead sperm whale. Bill was a colleague of my doctoral thesis advisor, Douglas Wartzok, and knew that I needed whale ears for my recent research project, but whale ears were not items one could trivially obtain. Indeed, access to any marine mammal ear was literally a matter of serendipity; would a whale or dolphin regrettably strand and die and if so, was there a chance to extract the tissue needed to explore how they hear in water.

Why would anyone pick a project dependent on chance, lucky, or serendipitous events. One answer could be naïveté or perhaps plain foolishness. Little did I realize at the start how much of my future work would depend on numerous instances of repeated, sometimes infrequent, fortuitous events. Serendipity was not the term that came to mind when this package arrived. In fact, the main reason I was now looking for whale ears and hoisting a package containing one of the largest ears on earth, was the result of a string of unpredictable events that at the time did not appear to be fortuitous.

The Concept of Serendipity

The term "serendipity" is widely acknowledged to have originated in the writings of Horace Walpole in a letter he wrote to Horace Mann in 1754 (Serendipity, Wikipedia) in which he described his novel word to mean a happenstance that leads, unexpectedly, to a discovery or insight. However, the concept of discovery by a fortunate, chance event has a far older provenance. In 1747, Voltaire published *Zadiq*, a philosophical work on the effect of fate. Both Voltaire and Walpole noted their inspiration came from a Persian tale, "The Three Princes of Serendip," that tells the story of three banished brothers who deduce from a series of tracks and marks left in the dirt that they were made by a camel that was lame and blind in one eye, ridden by a pregnant woman and carrying sacks of grain and wine. On reporting that they know where this camel may be, they are first accused of theft of the camel and sentenced to death, but after explaining their reasoning, are rewarded. There are even earlier versions of this parable of deductive reasoning from serendipitous chance clues dating back to sixteenth-century Venice and even in the writings of Rabbi Johanan bar Nafcha (180-279 CE) in the Talmud.

Later writers, including Huxley, Edgar Allen Poe, and Arthur Conan Doyle (Shades of Sherlock!) certainly made use of the same idea that there is power in observation of

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potentially relevant traces of events, if the eyes, ears, and brains of the individual are open to the unexpected. In science, examples of serendipity are even more frequent, such as the discovery of penicillin by Fleming from a contaminated bacterial culture, the discovery of Rh factors by Landsteiner and Weiner, and the nearly simultaneous discoveries of radioactivity by Becqueral and X-rays by Roentgen.

Some discoveries are not so evident nor quickly accepted, like the competing theories of how neurons work by Golgi (reticular theory that neurons are a fixed network) versus Ramon y Cajal (neuron theory of dynamic individual neurons producing a variable system). Both theories were based on observations on the same tissues using the same silver staining technique invented by Golgi. Despite their contradictory conclusions, the work of both was acknowledged in a shared Nobel Prize (Grant, 2007). The controversy between "neuronists" and "reticularists" continued well into the twentieth and twenty-first centuries, with translations of relevant publications by Cajal published in 1954 with commentaries and reviews by others published as recently as 2005 (Guillery, 2005).

Similarly, there can be unintended, adverse consequences to a serendipitous discovery. The eponymous Nobel Prizes were created by Alfred Nobel, who invented dynamite as an alternative to nitroglycerin to provide a more controllable explosive that would benefit mankind. The uses of explosives, of course, went fearfully far beyond those Nobel envisioned.

Chance Encounters and Positives from Negatives

The box described in **A Package in the Mail** was the start of a "project" to examine whale ears on which I was embarking as a new graduate student. It had sprung from a string of what I considered bad luck tinged with what proved to be invaluable chance encounters that continue to shape my research. My applications to doctoral programs had gone well, with several acceptances to prestigious and respected laboratories. First among them was an opportunity to work with Arthur (Art) Popper. By a quirk of fate, the arrangements for admission to his laboratory fell through when his departmental chair died unexpectedly. The delays that reapplication would have entailed resulted in my accepting another opportunity but meeting him was consequential to not just my intended graduate work but also to my growth as a scientist. I am continually grateful that Art has continued to be an extraordinary and invaluable mentor to me even though I was not able to formally join his laboratory. That disappointment, though, resulted in another opportunity.

The next step was hopeful but also a bit quirky. I was accepted into the laboratory of Douglas Wartzok, to whom I am equally grateful for his guidance and friendship but also his extreme patience with my quixotic path as a student. I had applied to work with Doug because of his excellent reputation as a marine mammal scientist. My goal was to work on neural processing of underwater sound in dolphins. I had trepidations about how things would go because Doug was a faculty member in the Johns Hopkins School of Hygiene and Public Health (JHSPH), Baltimore, Maryland, now known as the Bloomberg School of Public Health. The combination seemed odd, but it turned out that his appointment was related to animals as vectors, and he actually did have live seals in the building!

Another good sign was that the National Aquarium in Baltimore, Maryland, had just acquired several dolphins for its new tanks, and discussions began on access to them that would have entailed noninvasive recordings of brain activity. Shortly after I completed preliminary exams, expecting to start work with these dolphins, there was an unexpected event; the dolphins at the aquarium disappeared. In fact, they were removed to a facility in Florida to recover from multiple potential stressors, including sounds resulting from throngs of visitors and intermittent vibrations of their tank walls from adjacent maintenance equipment.

This was a setback, but the animals were expected to return within a few months. I opted to use the time to learn as much as I could about auditory systems, particularly those of aquatic mammals. It shortly became apparent that a wide variety of literature on whale and dolphin hearing did exist, but there were several opposing theories, not only about how but also what they could hear. In part, this was due to limitations on what forms of experiments and measurements could be made, not to mention the practicalities of adapting any recording gear to operate in water on animals of such exceptional size. Atop that, images in the literature on the anatomy of whale ears suggested there was great variability in ear structures but little on whether these variations resulted in differences in hearing across species.

A wise person might have said, "Back to models and measures of hearing in mice." Then the package arrived. Several elements converged that day. First, the received specimen was a large and dense block of bone with no hint of where within it there was anything resembling an ear. Second, the Johns Hopkins Department of Radiology was just across the street from our laboratory. Third, the head of the Neuroradiology group was Arthur Rosenbaum, who was amazingly welcoming to investigations that would explore the limits of radiographic imaging that he shared with the head of Experimental Radiology, James Anderson and his assistant Frank (Rusty) Starr. When I blithely showed up asking if they could X-ray this whale bone block to locate the ear inside, there was no hesitation. Not only did they locate the ear, they suggested we try their new Siemens computerized tomographic (CT) scanner that would not just locate the ear with greater precision but also provide sectional images of the inner and middle ear. That first set of scans opened my eyes to new avenues of research.

This whale ear was exceptionally dense compared to any bone the radiologists conventionally examined. In fact, it appeared to approximate the X-ray attenuation characteristics of soft metals. Because the Hopkins Hospital Radiology facility was relatively new, it was also a site at which Siemens was beta testing new imaging software. I was shortly introduced to their engineers who were interested in testing their ability to remove artifacts from scans of dense objects, like metal prostheses implanted in tissues.

I found myself in a perfect storm of equipment, ideas, and data that were totally unexpected, and because the dolphins were not back yet, the anatomical work continued. More packages arrived, and the more ears I was able to image, the clearer it became that there were multiple anatomical species-related variations in size and shape of whale and dolphin ears. Very few of these variations had been documented because of the difficulty of dissection of these extraordinary bones.

Some variations I found in these ears had been explored in land mammal ears, particularly dimensions of the cochlear canal and basilar membrane. The scanner, of course, had limitations of resolution compared with histology, but it allowed not just the measurements but also the reconstructing, viewing, and imaging of cochlear structures in three dimensions. This noninvasive imaging was a major breakthrough that substantially increased the accuracy of inner ear measurements and analyses without the time and potential distortions of decalcification normally required to investigate inner ear morphology. It soon became apparent that there were correlations between cochlear length and body size, but, more important, was that the shape and dimensions of the cochlear canal spirals correlated with differences in frequency ranges and peak spectra of vocalizations produced by different species. In particular, there were striking differences in the cochlear spiral curvatures that physically affected what frequencies of sounds penetrated the cochlea.

A year passed with still no live dolphins to test, but a larger focus than just describing the ears of a few species was emerging. A thesis project developed that would assess the biomechanical implications of anatomical variants of the inner ears of odontocetes, the toothed whales, that are known to hear and analyze ultrasonic signals in water and to use echolocation to image their aquatic environment. To accomplish this project required cooperation and guidance from multiple departments and individuals with a range of unique specializations, all of whom were available at Hopkins. In addition to those in Radiology, the Division of Computer Sciences and Alan Walker and Patricia Shipman of the Comparative Anatomy Department were especially valuable advisors.

Without the fortunate coincidence of all these individuals and resources, the project simply would not have happened and no functional insights on these ears would have been found. Nor would I have pursued my future parallel studies into the hearing of even larger, low-frequency specialized ears of elephants, baleen whales, and their fossil ancestors (**Figure 1**).

Another Twist to Inner Ear Spirals

Another completely unexpected chapter of research grew out of this experience. I was quite fortunate to be offered a postdoctoral position in the Eaton-Peabody Laboratory (EPL) that is located within the Massachusetts Eye and Ear Infirmary (MEEI) in Boston, Massachusetts. The EPL was the brainchild of Nelson Kiang. It is an amalgam of engineers, researchers, and clinicians, and,

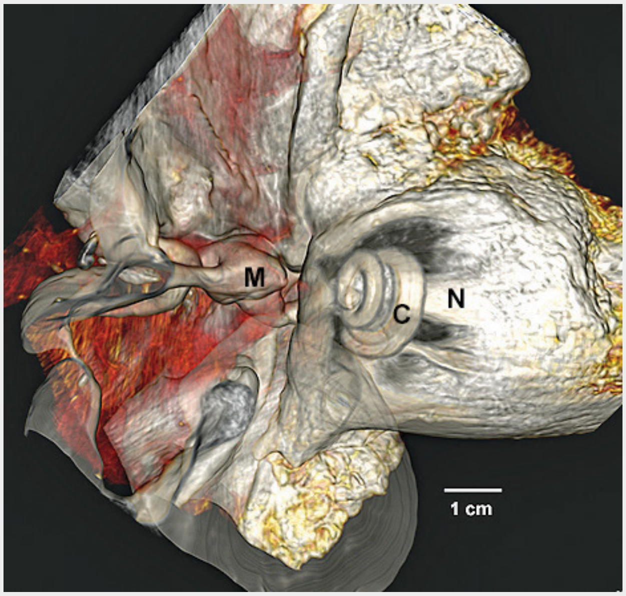

Figure 1. *Three-dimensional reconstruction from computerized tomographic (CT) scans of the middle and inner ears of a blue whale* (Balaenoptera musculus). *The bones surrounding the ear have been rendered translucent digitally to reveal the spiral fluid and membranous inner ear labyrinth of the cochlea (C), the auditory nerve (N), and the malleus (M), one of the three middle ear bones. A video of this reconstruction is available at acousticstoday.org/ketten-media. Images and multimedia used with permission, copyright © 2018 D. R. Ketten, all rights reserved.*

consequently, is a rich environment for blending basic and applied auditory research. Although I was ostensibly there to learn more about in vivo measurements of hearing, one day, in the hall, I overheard the chief of the Otolaryngology Department, Joseph Nadol, Jr., speaking with Donald Eddington, an engineer whose research group worked on cochlear implant design and measurements of implant patient postoperative auditory function. They were discussing the inability to determine the intracochlear positions of cochlear implant electrode arrays in individual patients and knowing whether any differences may affect patient results. The problem was that metal artifacts from the electrodes on postoperative CT scans obliterated visualization of much of the cochlear anatomy.

Admittedly, it was brash, but also irresistible, to volunteer that there were options to "fix" that. In the most courteous manner, despite understandable skepticism, Nadol suggested it may be possible for me to view postoperative scans for some patients and demonstrate whether the image processing I was suggesting could help. Because the scanners at the MEEI were Siemens machines, we were able to obtain the metal artifact reduction software that had been developed and tested on the Hopkins Hospital machines.

That accidental conversation led to my shifting my work at the EPL to over a decade of CT scan-based research on the imaging and individualized mapping of cochlear implants of patients at the MEEI as well as other implant centers, especially Margaret Skinner's group at Washington University in St. Louis, Missouri, and Mario Svirsky's at the New York University Langone Health, New York, New York. We did discover significant differences in implant distributions and, in many cases, developed a better understanding of how both implant array construction and surgical approaches may affect patient outcomes. Working on these practical issues that potentially improved patient outcomes was a radically different and rewarding experience compared with my then-limited experience of discovery in basic research.

The common thread to all of this was being open to recurring serendipitous opportunities to explore new ideas and use developing technologies that happened to be available to me. Even more important was learning from the wealth of mentors and colleagues who shared their ideas and knowledge at every step. The richness of collaboration should never be underestimated and seizing such opportunities should not be missed.

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Contact Information

Darlene R. Ketten
dketten@whoi.edu

Bioacoustics and Morphometrics
Boston, Massachusetts 02148, USA

My Career and Some Semiserious Scientific Serendipity

Jim Lynch

According to the Merriam-Webster Dictionary, serendipity has the narrow meaning of "finding pleasing things that one had not been looking for." In other words, unsought after good luck. Because random chance has a big role in luck (as opposed to how much of our luck/good fortune we consciously create), this distinction between luck and serendipity seems reasonable to make.

Because the theme of these *Acoustic Today* essays is "The Role of Serendipity in Our Scientific Careers," I would contend that the most serendipitous event in any of our scientific careers is the circumstances of our birth. We certainly don't get to choose the family we are born into or their circumstances.

If that logic is acceptable, I can state that my birth circumstances were reasonably serendipitous, though not perfectly so. I was born a white, male, Irish Catholic in the "technology happy" 1950s United States. These circumstances were favorable to the probability of a technical career. The religion part may seem odd, but the Catholic schools at that time were very good, so my education through high school was quite adequate for entry into a technical career. (It was less so as far as socialization is concerned, because these schools separated boys and girls at the time.)

Less serendipitous was my socioeconomic background. Not being born into a professional, academic, or well-off family lessens the chance for higher education. My family was one of many where the parents were World War II veterans and children of the Great Depression of 1929. But, due to a rising middle class at that time and aided by the GI Bill that provided college funding for veterans, my father was able to go from longshoreman to co-owner of a small marine and industrial electrical contracting company, and our family's financial picture rose. I'm not sure if the change in the fortunes of the United States' middle-class rates as serendipity, but it fulfilled the financial requirement for my higher education, if just barely. It also allowed me to work summers and vacations on ships, at construction sites, and in factories and so to understand how hard blue-collar jobs can be outside the academic sphere that I've inhabited since starting graduate school. I regard the opportunity to have that bit of real-world education as very serendipitous.

Because one expects to make friends and have inspiring professors in college, I won't call the influence of a good friend and an enthusiastic physics professor serendipity. But I would say that my interaction with those two people at the Stevens Institute of Technology, Hoboken, New Jersey, firmly cemented my career direction into physics. An electrical engineering degree would have sufficed to aid my joining the family business after graduation, but a physics degree promised a future that could actually be exciting to me. This type of decision is a common experience at the undergraduate level, so I won't belabor it.

After undergraduate graduation, I enrolled at The University of Texas at Austin (UT Austin) as a graduate astronomy major, and at this point, I can relate an event that I regard

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as quite serendipitous, my encounter with the astronomy graduate advisor. Unlike the inspiring encounters I'd had in the past with science faculty, there was an immediate antipathy between us. My request to take some courses in the Physics Department, as opposed to a (too) basic refresher course that he insisted I take, widened the initial gap into a chasm. So, being utterly naïve about interdepartmental politics and the fight for students, I walked down to the Physics Department office that was happy to admit me into *their* department. When I returned to the astronomy advisor with my story, I was admitted to the "persona non grata" club in astronomy, which thankfully only lasted for a year or two. (I later took my "outside of main field" course requirement in astronomy and am now president of an astronomy club on Cape Cod, Massachusetts [see capecodastronomy.org].)

The next bit of serendipity occurred when the Atomic Energy Commission shifted some of its funding away from university grants to support their new Los Alamos Meson Production Facility (LAMPF), Los Alamos, New Mexico, which in the end resulted in some UT Austin physics graduate students (e.g., me) being shifted to research assistantships. A year before finishing my PhD thesis, I was made an assistant at UT's Applied Research Laboratories (ARL:UT) and began to learn about sound in the ocean. My acoustics career had begun through no impetus of my own. The late Bill Kuperman's (see bit.ly/kuperman) saying "nobody starts out in ocean acoustics" was somewhat of a truism in the 1970s, and I was one of the people who were part of that era. I had also wound up back in the ocean, which had been my family's heritage back to its roots in Ireland. So, in a funny way, I have to question whether this was serendipity (as I've had a wonderful career) or simply fate.

After finishing my PhD degree, I stayed on at ARL:UT, which offered me a good salary and a permanent position. Being newly married (another piece of serendipity as neither I nor my future wife, Chris, were looking for more than a random tennis game when we met), having such an offer was manna from heaven. We stayed in Austin for three more years, enjoying the vibrant culture of UT Austin, Austin, and Texas in general.

But other parts of life also tugged on us. A newborn daughter and the illness of Chris' father eventually pulled us back toward our roots in New Jersey and the Northeast. So, we started looking for possible new opportunities, which is when the next bit of serendipity occurred. While I was "rounding up the usual suspects" to send my résumé to, Chris was leafing through the current *Physics Today* magazine. She spotted a "sailboat" logo that she thought was catchy and asked me if this place "Woods Hole Oceanographic Institution," Woods Hole, Massachusetts, did anything like what I was doing at ARL:UT. Because I did know of George Frisk and Bob Spindel (Acoustical Society of America [ASA] Silver Medalists), two faculty members at WHOI, by reputation, I figured, "Sure, let's send them a résumé as well." A few months later, I was working there. I have now been there for over 40 years, currently as a retired emeritus scientist.

Let me switch gears some to discuss the academic/scientific serendipity I've experienced in my career. The switch to acoustics from quantum physics is, as many will attest, not an overly hard one because the Schroedinger equation and the Helmholtz equation are basically the same aside from a change of variables. If the universality of the mathematical basis of physics can be called serendipity, then all of us who have switched fields within the physical sphere have been beneficiaries. However, I don't think that the laws of nature had my changing fields in mind when they were generated and so perhaps my benefiting from that universality should be ascribed simply to good luck.

Meeting and eventually working with George Frisk and Bob Spindel at WHOI was fortunate because their work was how I initially recognized the Institution, but it was also by design and so not serendipitous. However, the strong oceanographic component of the work at WHOI was serendipitous for me. The fields of physical oceanography, biological oceanography, marine geology, boundary layer physics, atmospheric dynamics, and more were (mostly) new to me, and as anyone who knows me can attest, I *love* picking up new fields. I am a world-class technical-text bibliophile, and I even read what I buy. Moreover, when you approach a field that is totally new to you, you can ask really dumb questions, including about "well-known fundamentals," without being bogged down by standard wisdom. You are also often at the interface of fields, which we all know is fertile ground for new advances. And finally, if you make a dumb mistake, you can use the plausible deniability line of "well, it's not exactly my main area." (NOTE: You can only do this to a limited extent; people catch on quickly.)

But to be serious, this chance/license to shamelessly explore a huge breadth of scientific areas was perhaps the biggest bit of scientific serendipity during my career. The technical societies I belong(ed) to, the ASA; the American Geophysical Union (AGU); the Institute of Electrical and Electronic Engineers (IEEE); the Oceanography Society (TOS); and the American Physical Society (APS), also mirrored this. I won't deny being a kid in a candy store.

The last piece of serendipity I'll allude to is in my editorial role. While being a new scientist at WHOI, I came across the late Bill Carey as a sponsor for some shallow-water bottom acoustics work I was doing with George Frisk. Bill was also the editor in chief (EIC) of the *IEEE Journal of Oceanographic Engineering* (*IEEE JOE*) at that time and was headhunting for someone to pass the baton to. Playing shamelessly on our mutual Irish backgrounds, Bill lured me into a guest editor role and eventually into the EIC role. While in that role, Bill Carey, Bill Siegmann, and ASA Publications EIC Allan Pierce also worked with me as adjunct scientists at WHOI, and our conversations were as likely to be about publications trends as about ocean science. And then, as my role in *IEEE JOE* wound down, Allan Pierce inveigled me into editorial roles in ASA publications. The rest is history, and I would contend serendipitous.

The last bit of my story comes about more from design than by serendipity but is worth including because it rather completes the arc of my career trajectory. When I retired from WHOI, I wanted to spend some time doing amateur astronomy. In 2014, two years before I retired, Chris again serendipitously found a relevant advertisement, this time for a "100th Birthday Party" at an astronomical observatory on Cape Cod celebrating the observatory's founder, Werner Schmidt. We decided to go. After the party, we joined the Cape Cod Astronomical Society and have been active members ever since. Thanks to Chris, some serendipity, and our admittedly "Plugger" mentality, we have been able to explore and enjoy both sea and sky during our lives. Not a bad lot to have drawn. (As an aside, "Pluggers" is a comic strip that was created by Jeff McNeely that relies on reader submissions [see gocomics.com/pluggers]. It describes thrifty, working-class people who have a mentality typical of the baby-boomer generation and are a bit out of touch with modern times. They are portrayed as anthropomorphic animals, often bears. I highly recommend it!)

Contact Information

Jim Lynch
jlynch@whoi.edu
Woods Hole Oceanographic Institution (WHOI)
266 Woods Hole Road
Woods Hole, Massachusetts 02543-1050, USA

Guided by Serendipity: The Influence of Teachers on My Acoustics Career

Andrew Morrison

I feel fortunate to have been a part of the field of acoustics since 1997. I suspect that most people involved in any field for this long have had their journeys marked by unexpected twists and turns. My experience has certainly been nonlinear. When I think back to the moments of serendipity that I have experienced, I think of the people who were there to advise and guide me along the way.

Most of my job responsibilities are in teaching introductory classes in physics, acoustics, and astronomy. Looking back as to how I got to this point, I see numerous examples where teachers guided me and influenced my decisions. These interactions seemed small and inconsequential when they took place, but with hindsight, I can now identify how serendipitous my exchanges with my teachers were to my life and career.

I can trace my path to acoustics back to my childhood. I remember for an elementary school project in Des Moines, Iowa, I chose to learn how electronic synthesizers worked. It was the 1980s, and all the music playing on the radio seemed to use electronic keyboards, synthesizers, and drum machines. I went to the library determined to learn how these devices worked so that I could explain it for my project. I am sure I did not understand most of what I found at the library. But I became more convinced that I wanted to have my own keyboard to play at home.

My parents insisted that I first learn to play the piano before they would consider getting me a keyboard. So I started taking piano lessons that lasted through high school. One of my first piano teachers was a music major at a nearby university. After a few months working on the mechanics of how to use each hand to play different parts of simple piano pieces, my teacher would include a few bits of music theory to explain why the notes on the staff were organized the way they were. To her surprise, I was interested in learning what she was showing me!

In my first year of piano lessons as a fourth grader, I learned a small amount of music theory. It was likely just a fraction of what a college-level music theory class would cover. Looking back now, I see how serendipitous it was to be shown mathematical connections to the music that I could play and the music that I listened to. It was fortuitous for me that my teacher would explain music theory to a kid learning the piano. Looking back now, I am thankful that I paid attention and responded to these tangents to the main lesson.

That piano teacher was the first person who connected music with math for me. Soon after those lessons where we worked on the math of music theory, she would graduate from college and move away. I found other piano teachers, but none who integrated music theory with my piano playing as much as my first teacher. The mathematical connections to music came at a time in my life when science and math classes were starting to become my favorite subjects in school. I took as much math as I could through elementary and middle school.

After starting on the piano, I also had the opportunity in middle school to learn to play the saxophone. For a few

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years, the piano and saxophone were my main musical instruments. I have an older cousin who I have always looked up to, who was at that time an accomplished jazz trumpeter. I had a few opportunities to hear him perform while I was still learning the basics of these instruments.

By going to jazz concerts and listening to jazz albums, it was obvious to me that the rhythm section in the jazz band would be the most fun; the bass, piano, and drums rarely stop playing, unlike the winds where the players periodically take a break to catch their breath. A week after starting high school, I told the band director I wanted to play piano in the jazz band. The director, in turn, convinced me to play the bass drum in the marching band's drum line. After marching band, I went back to playing the saxophone in the concert band my freshman year of high school.

My decision to join the marching band a week into the school year meant that my class schedule had to be changed because bands met when I was scheduled to be in geometry class. The high-school counselors found another section of geometry that worked with my new schedule, although it was with a different teacher.

That teacher, Mr. Marter, must have recognized how much I liked math. Before the end of the year, he told me about a summer program at Iowa State University, Ames, for high-school students interested in math and science. I applied for that program and was accepted into it. That summer math program was my first introduction to mathematical modeling. We learned how to mathematically describe predator-prey interactions, the spread of viruses through a community, and the wonders of Conway's Game of Life (see playgameoflife.com). I had such a great time in this program that I applied and was accepted for a second summer the following year.

I never had Mr. Marter as a math teacher after my freshman year. However, during my last year of high school, I ran into him in the hallway. He asked if I had thought about what I might study in college. I said that although I wasn't certain about a major, I was leaning toward trying to major in mathematics based on my experiences in the summer math programs and math classes throughout high school. He suggested I should go the University of Northern Iowa (UNI), Cedar Falls, for their Science Symposium Scholarship competition.

This chance hallway encounter with my former math teacher was definitely a moment of serendipity for me. The conversation opened many opportunities for me that would shape my life in countless ways.

Mr. Marter pointed out that each STEM department at the university would be making scholarship awards, but the scholarship was for any STEM major the college offered, no matter which department a student competed in. He suggested there would be many students entering the math department's competition, but significantly fewer students trying for the physics department's scholarships. I agreed that it was a mathematically savvy choice to play the odds with a smaller pool of students to compete against.

On the day of the competition, Mr. Marter drove me nearly two hours to the university where I was given an hour-long test on various topics in physics. While the tests were scored, there were tours of all the physics research laboratories. One of the laboratories was an acoustics laboratory where I first met Peter Hoekje (see bit.ly/3WRNCWt). The laboratory had an anechoic chamber that had been constructed by previous students. There were also several projects on display, one of which was a demonstration of a thermoacoustic refrigerator. I was completely blown away that sound could be used to manipulate temperature! For me, this laboratory was the highlight of the tour.

I did well enough on the test to be invited for a scholarship interview after lunch. I don't recall much about that interview, other than Peter Hoekje helping me find the right words to express why I thought I liked physics more than the other sciences. At the end of the day, I placed third in the physics competition, which meant I had been awarded a small scholarship for the first two years of college.

By the end of the school year, I learned that one of the two people who had placed ahead of me in the competition had decided not to attend UNI, meaning that a full tuition scholarship was available to me. I accepted the scholarship and became a physics major that fall.

For some time in college, I tried to keep playing music a part of my life. I played in the marching and pep bands for two years in college. I was tired of carrying a bass drum in marching band. Instead, I switched to the trombone, an instrument I learned in high school.

My freshman physics laboratories were in the afternoons. Band rehearsals were in the early evenings on the same days as physics. Carrying a trombone across campus, I would go from physics laboratory to the cafeteria for dinner and then to band rehearsal. One day, a physics laboratory partner kindly invited me to join her and her friends at the cafeteria. What I didn't know was that by accepting this invitation, I would meet the friend in that group, Renae, who I would marry five years later. I look back on that dinner invitation as one of the most serendipitous moments of my life! Had I not agreed to dinner, I may never have had the chance to meet my wife.

After a year of physics classes, Hoekje invited me to work on some projects in his acoustics laboratory. One of the first projects I was a part of was attempting to determine how much the vibrations of a trombone's bell contribute to the total sound radiation from the instrument. Part of this project involved a visit to Northern Illinois University (NIU), DeKalb, to use the TV-holography system in Thomas Rossing's (see bit.ly/3AkDbBX) laboratory. The project resulted in my first Acoustical Society of America (ASA) meeting presentation (see doi.org/10.1121/1.418711) in June 1997.

The visit to Rossing's laboratory was another instance of serendipity for me. I could see the possibilities of continuing to study acoustics. I was grateful that he would take me on as one of his graduate students in his laboratory, so less than a week after Renae and I were married, we moved to DeKalb so that I could start my PhD at NIU under Rossing's guidance.

While at NIU, I learned that all graduate students begin with knowledge gaps, often assumed to be purely academic. However, these gaps extend beyond missing coursework or unfamiliar academic content. For instance, I didn't understand how my graduate program's funding worked.

Early in my first year, a graduate student advisor informed me that the physics department would fund me as a teaching assistant for the five years needed to complete my degree. I did not know to apply for graduate fellowships until after being in graduate school for more than two years, meaning I missed the opportunity to apply. Although some graduate students might have been frustrated by not securing a research assistantship, I saw the teaching assistant role as a chance to gain valuable classroom experience. It took years after graduating to realize how fortunate I was to have had that guaranteed support.

Being a teaching assistant for more than just a year provided me with unique opportunities that I otherwise wouldn't have had the chance to pursue. By the time I had finished graduate school, I had become manager of the university observatory, taught every introductory laboratory course, and had even taught sections of the introductory astronomy course.

Other smaller opportunities would also come my way, such as invitations from civic organizations such as local Rotary Clubs to give a presentation on something related to science. Once I was asked to teach a noncredit short course in astronomy for NIU's continuing education department. It was only a couple of sessions, but strangely, this course made me more nervous than the regular astronomy course I was teaching to college students. I decided to make the best presentation I could and do my best to disguise my nervousness. I am pretty sure that at least one person in the class could sense my anxiety because at the end of the last session, this attendee assured me that I was a "natural teacher" (her words) and that I should keep doing what I was doing. I don't know if I believe in the idea of a natural teacher, but I appreciated her encouragement.

While in graduate school, I was introduced to many gifted educators thanks to Rossing and his passion for physics and acoustics education. He brought me to many physics teacher meetings, including local physics teacher alliance meetings and section meetings of the American Association of Physics Teachers. Through these meetings, by listening to other teachers and asking questions, I came to see that meaningful teaching was more than just being a subject expert and explaining the topic to a room full of students. I became fascinated by the work done in the physics education research community. By learning from those who study how best to teach, I started to improve my teaching practices.

I can draw a straight line from these experiences in graduate school to my first academic job after graduate school to the current position in teaching physics and astronomy at Joliet Junior College (JJC), Joliet, Illinois, a two-year college near Chicago. When I started at JJC, I proposed a general education course in musical acoustics. My main motivation for proposing the course was that I wanted to continue to teach a course that I loved. What I didn't know at the time was that the music department was starting a certificate program in music technology and that the allied health program was starting a degree program in diagnostic medical sonography. Both programs needed my course as a prerequisite; serendipity is everywhere!

For me, there have been many small moments of serendipity that have helped me get to where I am today. Sometimes, I can point to a specific person at a moment in time, like my first piano teacher or my high-school math teacher, who provided that nudge that would come to dramatically shape my career trajectory. In other cases, the interactions would be spread over longer time as in the case of being mentored by Tom Rossing.

When I look back, I'm struck by how I often did not recognize the serendipity in the moment when it occurred. The people in my life have given me many chances to grow personally and professionally. By choosing to say "yes" to new opportunities, these serendipitous events have shaped my journey in countless ways. I view many situations as opportunities for learning or growth. Although not every opportunity has borne fruit, I still approach challenges as opportunities and look later for the serendipity that resulted.

Contact Information

Andrew Morrison
amorriso@jjc.edu

Department of Natural Sciences
Joliet Junior College
1215 Houbolt Road
Joliet, Illinois 60431, USA

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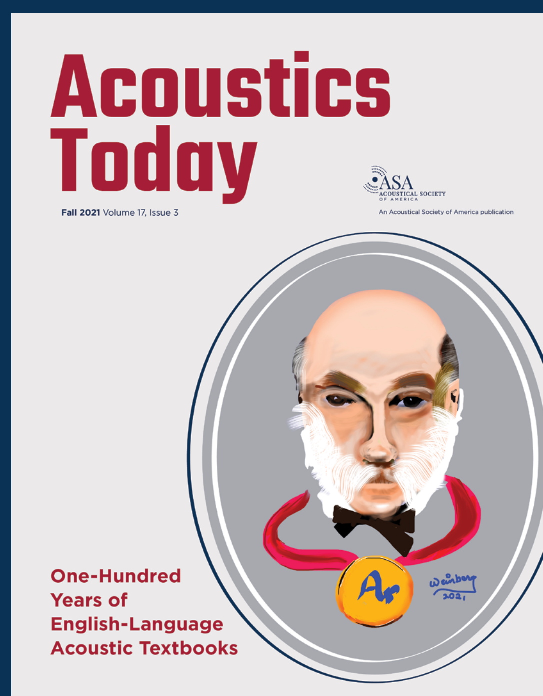

Blending Music Architecture and Acoustics

Paul H. Scarbrough

Like many people, I never set out to make a career in acoustics, and when people ask me how I got into acoustical consulting, I literally respond "by accident." I recall two shaping influences in my early life. The first was music. My parents exposed us to a broad range of music while growing up. Their eclectic album collection included everything from Eugene Ormandy conducting the Philadelphia Orchestra to Broadway show cast recordings to Herb Alpert and the Tijuana Brass. My mom's car radio was always tuned to WLFN, Philadelphia's classical music station (after several ownership and call sign changes now sadly just another top ten hits station). My exposure to music, particularly classical music, deepened at my high school, Archmere Academy, where Paul Clemens taught an extraordinary survey class on the "History of Music," starting with Gregorian Chant and walking us through the Renaissance, Baroque, Classical, and Romantic eras right up and into the twentieth century. So began a lifelong interest and love of classical music.

The second influence was architecture. For reasons I cannot explain, the built environment always fascinated me. One of my earliest memories is being taken to the World's Fair in Flushing Meadows, New York, New York, during its second season in 1965 and arriving in the oval waiting room of the then new Pennsylvania Station, a space that seemed grand only because as a three year old, I had no recollection or knowledge of the much grander McKim Mead and White landmark it had replaced. In early grade school, I found myself drawing plans of houses that I might build sometime in the future. Perspective drawing and drafting classes in high school fed this interest. And so, when it became time to think about college and the future, it seemed only natural that I would go to architecture school.

A First Serendipity

While I was pondering prospective colleges, my father shared a book he had been reading, David McCullough's (1971) *The Great Bridge, The Epic Story of the Building of the Brooklyn Bridge.* In his captivating narrative, I read of the Roeblings, John, Washington, and Emily, who conceived, designed, and constructed the Brooklyn Bridge. John was the original chief engineer for the bridge. Washington succeeded his father after John died from tetanus following his foot being crushed by a ferry boat during a survey of the bridge site. Emily quietly became the liaison between Washington and the bridge engineers and contractors after her husband contracted the bends from his frequent visits to the caissons used to dig the foundations for the two great towers.

Serendipity intervened when I read that Washington Roebling had trained as an engineer at the prestigious Rensselaer Polytechnic Institute, Troy, New York (see rpi.edu). Reading *The Great Bridge* led me to research more about "RPI" as it is more commonly referred to, and I discovered that its graduates had been responsible for a vast panoply of advances and achievements in engineering and science, from television to the moon landings. I thought that a place that had fostered such creativity must indeed be special. After considering a number of architecture schools, my parents deposited me in Troy for my freshman year at RPI. It would be a decision that I never regretted, and absent David McCullough's book, RPI might never have come to my attention.

A Second Serendipity

At the end of my freshman year at RPI, J. Christopher Jaffe (see bit.ly/4gxefb9), an RPI alumnus from the

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Class of 1949, was awarded an honorary doctorate in recognition of his successful career as an architectural acoustician. Simultaneously, he was invited to join the adjunct faculty in the School of Architecture. In the fall of 1980, he began teaching an elective course in architectural acoustics. The class would meet once a week for three hours in the evening. Chris would lecture for maybe one and a half hours before he would reach his limit. He would then spend the rest of the class sharing slide images from his massive photograph collection of concert halls, opera houses, drama schools, and amphitheaters from around the world. The slides included both his work and the work of other acousticians and examples of contemporary projects as well as storied historical concert halls and theaters. We were fascinated as young architecture students, finding the thought of designing such important public buildings to be a real rush compared with the more prosaic projects that dominated our studio classes.

During my sophomore year at RPI, I was also tapped to chair a student committee that was to raise funds for a performing arts center on campus. Not surprisingly, the Institute's development office identified Chris Jaffe as an ideal prospect, with his work so intimately connected to the performing arts. Over Christmas break, two committee members, me included, joined an RPI development officer to meet with Chris to ask for his support. Chris generously agreed, giving us our first major gift toward the campaign. The meeting was a serendipitous way for me to learn more about Chris' fascinating work in acoustics. It also gave me a chance to stand out among the dozen or so other students in Chris' class at RPI. This would open a door to another opportunity in a couple of years.

From Summer Intern to a Career in Acoustics

After my fourth year in architecture school, I was passing through Connecticut to visit a former RPI roommate and his family on my way home to Philadelphia. My friend had graduated from RPI in mechanical engineering the previous year and had gone to work for Jaffe Acoustics (later Jaffe Holden Scarbrough Acoustics and now JaffeHolden) as an audio designer. He knew I was looking for a summer job and suggested I give Chris Jaffe a call to see if he might be open to having an intern in his office for the summer. I phoned Chris and he invited me to stop by his office the following day.

After a pleasant chat, Chris attempted to deflect my inquiry about a summer internship, but instead of simply saying no, he said that the company was really tight on space. This was absolutely true because the office was split between two suites on opposite sides of the corridor serving that floor. It was an awkward arrangement, but they made it work. Now I have never been the master of the one-line comeback, but serendipity possessed me at that moment, and I responded, "Well, I don't take up much room." That turned out to be just enough to disarm Chris, and he told me to come by the following day, which I did. At the end of the day, Chris stopped by my makeshift desk and told me I could start on Monday.

At the end of the summer, I did not return to architecture school because I was having second thoughts about a career in architecture but had no clear idea what I might do instead. Chris graciously extended the internship, and a month later approached me about working as his executive assistant. I readily agreed and soon found myself immersed in the details of managing his busy schedule, coordinating meetings and correspondence with his clients, handling routine administrative tasks, and liaising with the different departments in the office. As the expression goes, it was like drinking from a fire hose, and I quickly learned a lot about how Chris had built his practice into one of the top firms in the country. Chris Jaffe was an incredible mentor who shared his knowledge and expertise generously with me.

Chris soon discovered that my RPI experiences had included significant extracurricular work in student government, including a year serving on the Executive Board, followed by a year as President of the Union. In this latter role, I effectively chaired the Board of a $4.5 million operation, overseeing a full-time professional staff of 20 people and a part-time student staff of dozens more. Through this experience, I had gained important skills in finance, human resources, and planning, all of which Chris would put to good use as his firm moved to new offices and doubled from 10 to 20 people. Within a few short years, I was essentially managing the business aspects of the firm as vice president of administration.

In the early 1990s, Jaffe Acoustics found itself inundated with new projects. We needed to add another architectural acoustician to the team to handle the sudden increase in our workload, but there were few prospects out there as other acoustic consultancies were in much the same position. As we sat around the conference room table strategizing how we would try to find suitable candidates, Chris suddenly looked up and said, “Why go through all the effort to recruit someone from outside the firm? Why don’t we just train him?” and pointed at me. Thus began my transition to a consulting role in the company, first by participating in design work sessions in the office and later accompanying Chris and other Jaffe colleagues to meetings with clients and architects. Soon I was given my first project to manage (the renovations to the New Victory Theater on 42nd Street in New York (see bit.ly/3TEV3y6), and within a few years, I had a full roster of projects that included work with the Kennedy Center in Washington, DC, and with the renowned Cleveland Orchestra, Cleveland, Ohio, and working with celebrated architects like Pei, Cobb Freed, Hugh Hardy, David Schwarz, and many others.

In 2000, the time came to move on from Jaffe Acoustics. Initially I worked closely with Peter Barnett and his firm AMS Acoustics in London, United Kingdom. A year later, I was back in the United States where I partnered with Russ Todd and Chris Blair (and later Anthony Nittoli) to found a new acoustical consulting firm that we called Akustiks (see akustiks.com), a play on the phonetic spelling of acoustics. In the over 40 years since I first walked into Christopher Jaffe’s office, I have had the honor and pleasure of working with wonderful performers and artistic directors, collaborating with extraordinary architects, and completing numerous rewarding projects. What I discovered was that working in acoustics was an ideal way to marry a love of music and a love of architecture and work in both fields together. But none of it would have happened without my parents, Chauncey and Frances Scarbrough, exposing me to music from an early age, giving me first-rate educational opportunities, and encouraging my interest in architecture along with a happenstance encounter with a book that would lead me to RPI and my learning from and working with Christopher Jaffe. If that’s not serendipity, then I don’t know what is.

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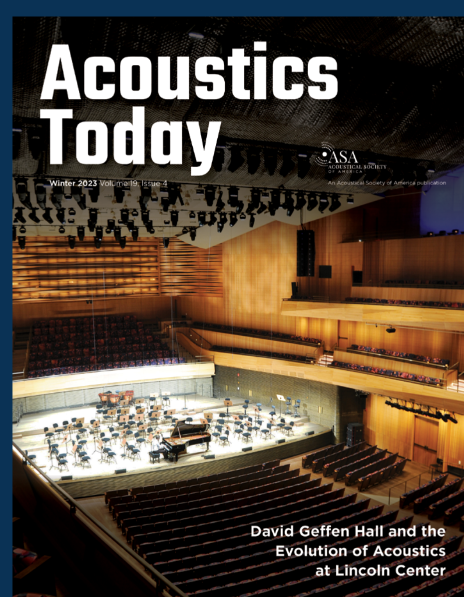
Contact Information

Paul H. Scarbrough
pscarbrough@akustiks.com
Akustiks, LLC
101 Merritt 7
Suite 300
Norwalk, Connecticut 06851, USA



My Serendipities: From Social Science to Soundscape

Brigitte Schulte-Fortkamp

When I reflect on serendipity in my research and teaching, I have asked myself whether the events I want to talk about are comprehensible to others. After all, what are these events: lucky coincidences or a series of consecutive events that defined the trajectory of my career? Some encounters are indeed coincidental. Spontaneous questions and answers during a conversation may result in actions that come together to initiate events that make a difference or lead to a new direction in life. My definition for the purposes of this essay is that serendipity arises in the presence of open-mindedness, critical observation, and the ability to recognize and capitalize on unexpected opportunities or connections. It is a fundamental aspect of human creativity, scientific discovery, and innovation across various fields and disciplines.

Many fortunate circumstances have shaped my scientific life. At the beginning of my professional career, I opted for the social sciences, phenomenological sociology and applied psychology. Insights into social contexts, particularly through participation in surveys conducted by established research institutes, led me to the analytical aspect of the social sciences and to my first book on work and society in 1978 (Schulte-Fortkamp and Wallmuth, 1978). At the University Göttingen, Göttingen, Germany, luck was on my side as I was able to work with a particular group of sociologists whose influence led me to recognize and analyze inequalities in social contexts.

I applied my new perspective when I started to work at the Ruhr University Bochum, Bochum, Germany, in planning an interdisciplinary training program in natural and social sciences. A few years later, I applied successfully to the Reform University Oldenburg, Oldenburg, Germany, where I initially worked on interdisciplinary concepts for teacher training, and then, serendipitously, I found my place in acoustics!

My encounter with acoustics was the decisive turning point in my career. At the Reform University, I had the opportunity to restart my scientific life in the context of the natural sciences and the important role of acoustics in everyday life. My serendipity specifically in acoustics was the result of unexpected, fortunate discoveries that occurred while studying sound and acoustic phenomena.

Working with scientists from different disciplines, I was impressed with their incredible commitment to applying science for changing lives. Adopting that viewpoint has allowed me to focus on applied science and on research that has brought a new approach to the science of acoustics. I realized that the absolute sound level is not the defining question for human listeners. Rather, the perception, the meanings of different sounds in specific contexts must be quantified and understood.

In my search for like-minded ways of thinking, I found the concept of soundscape! Specifically, discovering the acoustical analyses applied to sound reception and perception in the musical world was my moment of serendipity. This enabled me to consider a new approach

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in noise research, in particular, the many unaddressed questions with regard to exposure to community noise.

At the same time, work that was being done in Europe as a foundation for developing a Future Noise Policy (European Commission Green Paper, 1996) came to my attention. From my point of view, this was a joint awakening in relation to the purely mathematically derived approaches for explaining and addressing stressful acoustic situations. As stated in the International Organization for Standardization (ISO) 12913-1:2004 (2014), soundscape research represents a paradigm shift because it involves applying methods from the social sciences and physical measurements to account for the diversity of soundscapes across countries and cultures. Moreover, environmental sounds are treated as a potentially useful resource rather than as strictly a source of unpleasant sounds. The scientific discourse about the soundscape concept led to the development of advanced methods and tools that allow the systematic collection of soundscape-related data. The discussions about data collection finally led to international standardization efforts that fostered broader dissemination and application of the soundscape concept that defines soundscape as "any acoustic environment as perceived or experienced and/or understood by a person or people in context" (ISO 12913, 2014).

My experiences on the joint work on soundscape with my American colleagues were especially wonderful. I remember with gratitude the discussions with my great colleagues at MIT, Cambridge, Massachusetts, the many inspiring interactions at the Technical Committee on Noise of the Acoustical Society of America (ASA), and in the many special sessions at the ASA or Inter-Noise conferences. One of my greatest strokes of luck was my professorship at the Institute of Acoustics at the Technische Universität (TU) Berlin, Berlin, Germany, that gave me the opportunity to make soundscape research a subject of university education in acoustics. Sometimes researchers encounter unexpected challenges or obstacles in their experiments, which can lead to serendipitous solutions. For instance, while trying to address a specific acoustic problem, they may discover a workaround or alternative approach that turns out to be more effective than the original method. Serendipity often occurs at the intersection of different disciplines. Acoustic researchers may find inspiration or solutions from fields such as materials science, biology, or engineering, leading to unexpected breakthroughs in understanding or manipulating sound.

Modern research on the impacts of noise is no longer conceivable without the soundscape approach. Sound is everywhere, sound is perceived by people, and people decide whether sound is noise or not.

The components of a soundscape cannot be measured with conventional "sound levels" because the meaning of the sounds to the receiver and the context are important. The people affected are the best experts, so they are also the best "measuring devices." When participation is sought from the general population, the soundscape approach closes the circle between project planners and those affected in a very natural way.

The "Nauener Platz" project in Berlin, Germany, is an example of how cooperation can work. A small urban park was redeveloped from 2006 to 2009 with scientists working together with the residents in the area, based on a collaborative soundscape approach. Along with a group of my students, I was able to contribute to a systematic solution for the socially and acoustically strained square in the joint stakeholder project using the holistic soundscape approach (for more information, see Schulte-Fortkamp et al., 2007; Brooks et al., 2014). The result was the development of a cohesive new design for a neglected space based on a mixed methods approach that combined different soundscape elements, including the implementation of audio islands that are benches providing natural sounds as birds chirping and fountain splashing by pushing a button.

My guiding principle, like a credo, in this project was that the real experts are the people affected, whom we call "local experts." From them, we learn the meaning of the sounds in their environment, which sounds disturb them, which sounds they like, and which ones are important for the identification of the place (e.g., bird sounds in a tree-filled space). Together with the local experts and a group of additional stakeholders such as architects, city planners, and administrative officials, the Nauener Platz was turned into a vibrant space for the people who live there. Most importantly, their suggestions, their sound wishes, and their ambitions have preserved the Nauener Platz to this day (see bit.ly/4ey7qFn). This square has now been in existence for 15 years. Due to age, it is a bit rickety, but it still has importance to the residents. The encounters in the context of this project brought unforgettable moments of serendipity as my students and I learned from the local experts.

There are so many people in my scientific life without whom soundscape research and its establishment would not have been possible. I know it is always difficult to thank people by name because you do not want to forget anyone, so I will reference our book *Soundscape: Humans and Their Acoustic Environment* (Schulte-Fortkamp et al., 2023), where they are all named as chapter authors and in the references to their great publications. But in the context of serendipity, I must mention one encounter in particular. At the 2017 ASA Conference in Boston, I met, by chance, Art Popper. After a bit of conversation, Art suggested publishing the aforementioned book on soundscape in the Springer Handbook of Auditory Research series that he and Dick Fay founded.

Suddenly, there was the opportunity to bring together the knowledge gathered over more than two decades and to record it in a single volume! This would never have happened if I hadn't been able to talk to Art Popper directly in the corridor of the congress building about the possibilities and the necessary procedures. That was a great moment of serendipity!

Another serendipitous meeting was with the initiators of the International Noise Awareness Day in New York in 1997, which led to my initiation of the International Noise Awareness Day in Germany in 1998 that was supported by the German Acoustical Society (DEGA) and became a campaign of the DEGA. For 27 years, joint discussions with those affected and stakeholders have taken place in this context. This action has become a focus of interest in the national and international press. More importantly, those discussions have led to numerous solutions related to noise pollution.

Such chance events are always possible in acoustics or should I say, in the world of acoustic research. Acoustic researchers communicate worldwide through national and international conferences, workshops, and other scientific gatherings in addition to the countless publications on all areas of acoustics. The happy turning point in my professional career was my switch from the social sciences to applied acoustics. I will never forget how impressed I was at my first meeting of the ASA and the openness I experienced in international scientific discussions. Simply sitting down together, asking questions, and thinking about solutions together was inspiring.

Conference meetings also led to being able to break new ground by coming together in large, joint international projects such as COST TD0804 Soundscape of European Cities and Landscapes or the International Organization for Standardization. The objective of the COST project puts the goals in a nutshell. The main aim of the action is to provide the underpinning science for soundscape research and to facilitate significant advances beyond the current state-of-the-art through coordinated international and interdisciplinary efforts. The action will promote soundscape considerations into current legislation, policies, and practice, aiming at improving/preserving our sonic environment.

This project could only come about because our acoustical societies have the basic concept of bringing together the sciences and scientists from the field of acoustics and enabling communication with many colleagues during their conferences. The opportunity to be active in the various committees and functions for any of the acoustic societies also offers opportunities for serendipity.

A final very special serendipity for me. While attending an ASA meeting I was asked if I wanted to run for vice president of the ASA! I did, and after the successful election, I became the first non-North American ASA vice president. Also a few years later, I was given the honor of chairing the ASA's new International Liaison Committee. My involvement with that committee was a wonderful experience that left me with many thanks to all who served on the committee and brought together our diverse worlds in acoustics.

Sometimes serendipity involves a combination of chance, curiosity, and preparedness, leading to valuable outcomes that were not initially sought or anticipated. To be able to continue in acoustic research and to work together with other acousticians has been the greatest gift to me.

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Contact Information

Brigitte Schulte-Fortkamp
bschulte_f@web.de

Technische Universität Berlin
Einsteinufer 25
10587 Berlin, Germany

A Serendipitous Friendship

Kat Setzer

*Kat Setzer (**left**) and Liz Bury with the Haserot Angel at Lake View Cemetary in Cleveland, Ohio.*

If I were to look back at my career path to my current role as editorial associate for the Acoustical Society of America's (ASA's) Publications Office, I would say that it started serendipitously a little over 20 years ago during my freshman year of college at the University of Central Florida, Orlando. I chose to dual major in digital media and creative writing, despite coming from a family of mathematicians (actuary mother, college professor father, and two brothers who dual majored in computer science and math). I should note the issue wasn't so much that I disliked science and mathematics, just that I greatly preferred words.

Like many first-year college students, I basked in my new freedom, dyeing my hair purple and buying multiple pairs of JNCO jeans, which I wore with cartoon T-shirts from the kids' section at Target. (This is relevant.) These fashion choices seemed like the appropriate representation of my absolutely, undeniably artistic personality.

When I needed to take a science credit for my degree, though, I decided to take "Physics for Scientists and Engineers" because I'd excelled at my calculus classes in high school and wanted to prove to myself that I could do it. Behind me sat Bill, an aerospace engineering student with a mohawk and a penchant for surfing in the Atlantic (which was a short drive away). We bonded in the way two vaguely counterculture teenagers do, eating breakfast together after our early-morning class and occasionally going to on-campus events.

Bill introduced me to a few more folks along the way, including another first year from the neighboring dorm, a girl who intimidated me with her enviable style: knee-high purple-and-black striped socks, corduroy shorts, and an Invader Zim shirt. (Invader Zim, for those unfamiliar, was a short-lived cartoon about an adorable alien's inept attempts to conquer Earth.) I complimented her on her shirt, she on mine. As happens with serendipity, we ran into each other every so often that first year, but I didn't think much about her, assuming we were passing through each others' lives on the way to our final destinations.

I would go on to ditch my digital media major and devote myself solely to my creative writing degree, certain I would sell my first novel before I hit 25. My friendship with Bill, the aerospace engineer, only lasted that first year as our class schedules no longer aligned.

However, I kept running into the girl with the Invader Zim shirt: at parties of mutual friends, in various honors seminars, interning for the school's literary magazine, and tutoring students at the university's writing center.

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By our senior year, we still only hung out in the company of mutual friends, friendly acquaintances more than friends. During a shift at the writing center, we began discussing our plans for grad school. We both were applying to grad programs straight out of college. We both thought we wanted to teach creative writing one day — she poetry, I fiction. We compared the lists of schools we'd applied to and found we had one program in common: Emerson College's Master's of Fine Arts (MFA) in Creative Writing in Boston, Massachusetts.

"We should room together if we both get in!" she declared.

I agreed, although I didn't think there was a chance that we'd both end up there; MFA programs were notorious for small classes of only five or six students and, thus, never took more than one student from the same undergrad program in the same year.

As it turned out, perhaps serendipitously, I was wrong. We both got accepted to Emerson, and a few months later, we loaded all our belongings into a rental truck, which she would drive with her mother from Orlando to Boston. (I, never a confident driver, flew up to meet them and help unload.)

Thus, I became roommates with Liz Bury, the person who would eventually become senior managing editor of ASA Publications (read more about her at doi.org/10.1121/AT.2020.16.3.75).

After our first year of grad school, we both realized we didn't want to teach, that we were, in fact, better suited for the publishing world. I landed an assistantship at the school's literary journal and fantasized about a career as an editor ferrying the novels that I loved from rough draft to published masterpiece. (I suppose getting this assistantship was a bit serendipitous as well. Despite there being students with far better CVs applying for the position, my future boss told me he hired me in part because I'd brought a copy of the magazine to read while I waited for my interview. I didn't tell him I'd never read it before I applied for the job and was essentially doing some last-minute cramming.)

Liz, meanwhile, met her own moment of serendipity. A friend was leaving an internship at an ophthalmology journal. Would Liz want to apply? Ever pragmatic, Liz did, and so began her career in scholarly publishing.

In 2009, we graduated from Emerson. I only note the date because the United States was in the midst of a recession, which hit the publishing world especially hard. I spent my last few months of school under the impression a new role would be created for me at the literary magazine, only to find out a few weeks from graduation that the funding had fallen through. (Liz had better luck, thankfully, and found a role at another medical journal, this time focusing on kidney disease, which she started a few months before graduation.)

Facing this bit of antiserendipity, I scrambled to figure out my next steps. I found a few options that appealed to my sensibilities: one as a low-level editorial assistant for a textbook publisher's English department, another as an equally low-level assistant at a publisher of niche nonfiction books for a general audience. Maddeningly, both told me I was overqualified for the positions.

At this point, I probably could have asked Liz for advice about scholarly publishing. Instead, I decided I'd do something entirely unrelated to anything I'd done thus far (always a practical choice) and got a job selling gym memberships because, besides reading and writing, I also spent a lot of time working out. I told myself that I would be much more likely to write in my off time if I wasn't sitting and staring at a computer all day.

I applied to positions at a few gyms in Boston, but only got interviews with two: the gym I visited every day and a women-only gym that a few of my friends went to. I'd never gone there myself and was immediately concerned by their lack of "quality" equipment (which, for me meant Olympic bars, bumper plates, and all my favorite powerlifting supplies). Still, when I sat down with the membership director, I told her how, truthfully, I knew that typical gyms weren't appealing to everyone, and I respected that the company managed to make a safe workout space for women who didn't feel comfortable in normal gyms, like my friends. She ended up hiring me and the other gym did not. At the time, I felt a bit miffed; now that I've worked and exercised at a number of gyms, I realize this hiring was a lucky accident as well because

I ended up preferring the community there to any other I'd encountered. I would work there for seven years.

Time passed. Liz kept working her way up the scholarly publishing ladder. In 2010, after about a year handling memberships at the gym, I realized that most of the personal trainers wanted to focus on working with young athletes, even though our clientele tended to be older and less comfortable in the gym. Seeing an opening, I went on to get certified as a personal trainer, focusing on clients over 50 and those recovering from injuries. I spent my free time reading books about kinesiology and different training modalities.

After four years, though, I felt like my role had stagnated, with little room to challenge myself intellectually, so I decided to go back to school for either physical therapy or occupational therapy. The few science courses I'd taken in college had lapsed, so I signed up for the whole roster of introductory sciences (biology, chemistry, and physics) from a local continuing education program, then proceeded to work my way through all the prerequisites for the graduate programs while still juggling a full load of clients.

In 2015, around the time I would have started applying to graduate programs, I met someone. (This meeting, too, could be called serendipity; over dinner with a friend, the friend mentioned they met "a scientist who wears plaid" they thought I'd like, and proceeded to set the two of us up on a date.) As the relationship progressed, we started talking about things like marriage and having a family (as folks do). I worried that years of schooling and an entirely new career, now possibly balanced with family obligations, meant I would have little to no time to write. Although I hadn't written my great American novel, or any novel at all really, I still penned the occasional short story or essay, and I didn't want to give that up.

So I stuck with personal training, moving to a new gym in a new state when my then-fiancé took a postdoc in Cleveland, Ohio. By then, though, I'd outgrown the long hours training required. (Trainers at large gym chains like the one where I was employed were paid on commission and were expected to develop their own client bases, which meant staying at the gym all hours to find potential customers.) I wanted a steadier job that allowed more work-life balance. Thus, in 2017, I started looking for publishing jobs, although they were still sparse, and I didn't really know what I was qualified for at that point. Then, one week when I was in the midst of pondering this problem, Liz and her husband visited Cleveland. More serendipity. I asked Liz if she had any tips for looking for publishing jobs, and she mentioned that the society she'd just started working for that past year needed an editorial coordinator for their magazine, *Acoustics Today*. It was only part time, but it would help me get my feet wet again.

I applied, hoping maybe all those science classes I'd taken would be of some use. I got the job and thus began my career with the esteemed Arthur Popper. At first, I worked on *Acoustics Today* for a few hours a week and filled the rest of my time with freelance editing and writing. Over time, my role grew as I started helping with various tasks for the other ASA journals and created social media sites for our publications. One could say I even came into my most recent role, hosting the publications office podcast, a bit serendipitously as well; I took over the podcast after our previous host left. Because I already handled social media, it made sense for me to take the role over as well.

I've been with ASA Publications for over seven years now. I'm not sure if you told me when I was an idealistic college student that I'd end up in scholarly publishing how I would have reacted. (When talking to Liz about this article, she mentioned that there's a joke in scholarly publishing that folks rarely seek out the field but instead stumble on it.) I like to think my circuitous career path was serendipitous: how an acquaintance would go on to become one of my best friends and eventually help me discover a career path that fits my skill set. What I learned, albeit in a roundabout way, is that although I may not be as keen on *doing* science myself, I do like talking (and writing) about it, whether explaining to a training client about how a muscle or joint works or developing an interview with an acoustician about their latest findings.

Contact Information

Kat Setzer
ksetzer@acousticalsociety.org
Acoustical Society of America
1305 Walt Whitman Road
Suite 110
Melville, New York 11747-4300, USA

Serendipity in My Life

Kathleen J. Vigness-Raposa

Serendipity is that wily combination of being in the right place at the right time and creatively connecting that experience with disparate events that have occurred in one's background to chart a new path of exploration, sometimes considered an "ah ha" moment. This has occurred at several points in my life, fueling my passion for ocean acoustics outreach (earning the nickname "Kathy DOSITS") and crucial conversations about best practices for evaluating the risks of anthropogenic activities in ocean acoustic environments.

Both of my parents were teachers and several summers were spent camping and exploring the western United States. These experiences exposed me to extraordinary natural beauty and diverse cultures. One summer day while tide pooling along the California coast, we encountered a sperm whale that had stranded and died. Being from Wisconsin, this creature absolutely fascinated me, and I became passionate about studying marine mammals.

As many lovers of large megafauna can attest, it is a difficult journey to develop that expertise, and my parents were convinced I would never get someone to pay me to do something so wonderful. My undergraduate degree was in secondary science education from Miami University, Oxford, Ohio, which provided me with an incredibly diverse foundation in biology, chemistry, physics, geology, and mathematics along with educational psychology, teaching principles, and communication skills. This extensive background has provided me with an incredible foundation that has helped me make connections across a variety of disciplines.

I was fortunate to earn a spot in the master's program at the Graduate School of Oceanography at the University of Rhode Island (URI), Kingston, working with Howard Winn on analyzing acoustic recordings of minke whale vocalizations. One of the courses I took was on marine mammal population dynamics, taught by Tim Smith from the United States National Oceanic and Atmospheric Administration (NOAA) Northeast Fisheries Science Center. This was a serendipitous encounter because it was the one time that Tim taught at URI, and it made me think about the possibilities of integrating passive acoustics into population dynamics. At that time (mid-1990s), population dynamic surveys for marine mammals consisted of visual surveys, typically from a vessel or airplane, and analyzed with distance sampling statistics.

Distance sampling has several underlying assumptions. One of the foundational assumptions is that all animals are equally available for detection at any given time, that is, that the probability of detecting an individual, by whatever means being used, is 100% within a known area. This assumption is obviously not met with visual surveys for diving marine mammals. Statistics have been developed to deal with diving marine mammals, which led me to wonder if similar statistics could be developed for detecting vocalizing marine mammals during a passive acoustics survey. Spoiler alert! They could (Thomas and Marques, 2012); however, that work would come much later by statisticians; my focus was on the foundational knowledge needed to inform those statistics.

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"Discovery of Sound in the Sea"

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To use passive acoustics in population dynamics requires a fundamental understanding of each species' vocalizing behaviors and how those behaviors will affect the probability of detecting individuals. For example, do all individuals produce the same types of vocalizations (frequency, source level, signal length, repetition rate)? Do they vocalize with the same temporal patterns (diel variation, seasonality)? Do they vocalize in the same locations at the same water depths? My master's thesis was a simulation study of the diving, movement, and vocalizing behaviors of minke whales during a passive acoustics survey and a visual survey. By running many thousands of iterations of animals diving and vocalizing during simulated surveys, I looked at how each surfacing and vocalizing behavioral parameter influenced the detectability of individual animals. The ultimate question was: How well do we need to know the diving, movement, and vocalizing behaviors of a species to conduct surveys that would result in accurate population dynamics estimates?

Unfortunately, Howard Winn died of a heart attack after my first year at URI, but as serendipity would have it, that was just when James H. Miller came to URI's Department of Ocean Engineering (see bit.ly/3WQqHtw), which started a long-term collaboration that continues today (e.g., Amaral et al., 2020; Potty et al., 2023). Jim connected me with one of his colleagues from their time together as students at MIT, Cambridge, Massachusetts, William T. Ellison, founder of Marine Acoustics, Inc. (MAI; see bit.ly/46UtNkJ), where I started to work during my time as a master's student. This was also a serendipitous connection because my bioacoustics work complemented the mechanical/electrical engineering background of almost everyone else at MAI at a time when the potential effects of underwater acoustic exposure on marine animals was just beginning to be understood.

The simulation work I was doing to understand the importance of various behavioral parameters for visual and passive acoustic surveys informed parameters needed in the animal movement component of MAI's Acoustic Integration Model (AIM). AIM was built first in the computer programming language Fortran by Bill, then converted to Java to simulate the four-dimensional (threedimensional [3D] space plus time) interaction of diving and moving marine animals ("animats") within an acoustic field created by a sound source. The animats record their acoustic exposure at each time step; the recorded sound pressure level or particle velocity at each time step can be used to calculate each individual's overall exposure over a simulated activity (Frankel et al., 2002).

This development moved risk assessment analyses from simplistic zones of influence (ZOIs), where potential effects are estimated to occur out to a distance from an activity and animals are distributed in two-dimensional (2D) space based on their density (number of individuals per area). In that type of analysis, an animal within the ZOI range is affected and an animal outside the range is not affected. There is no consideration of water depth with acoustic propagation nor animal movement during the activity.

With models such as AIM, the animals and the anthropogenic activity are simulated in real-world scenarios, and at specified timesteps, the animals sample the environment, including the acoustic field. The output of each simulation is a time-stamped movement and exposure profile for each individual animal from which potential effects may be estimated. Animals can be programmed to respond to environmental features, and their densities and distributions can be predicted using geospatial statistics and landscape ecology principles, another serendipitous exploration during my PhD work at URI (Vigness-Raposa et al., 2010).

Another part of my master's career led to a long-term collaboration in developing the Discovery of Sound in the Sea (DOSITS) project (Vigness-Raposa et al., 2021), which has been a series of serendipitous events that have blended outreach education and underwater acoustics to develop world-class resources. As a student, I had an educational outreach assistantship with Gail Scowcroft (2023), working with educators, media professionals, and graduate students to incorporate marine science topics and processes into their daily work as well as developing educational outreach material on a variety of marine science concepts.

In later years at MAI, I was conducting risk analyses for underwater acoustics experiments funded by the Office of Naval Research (ONR). One of the research cruises coincided with an operational United States Navy military training exercise in the Providence Channels of the Bahamas, which resulted in a multispecies mass stranding of 17 cetaceans (Evans and England, 2001). In trying to field questions from legal teams, public affair officers, program managers, and the general public, it became clear that there were no resources readily available to explain the fundamental scientific principles of underwater acoustics.

I started collaborating with Peter F. Worcester at Scripps Institution of Oceanography, La Jolla, California, to develop an educational website on underwater sound, but thankfully, serendipity stepped in and reminded me of my foundational roots with Gail Scowcroft. Peter, and I soon realized that as much as we loved the science of underwater sound, we needed to expand our team to include educational outreach and communication professionals, which was unique in marine sciences at the time and really only occurring with large NASA projects. The DOSITS project was launched in 2001, with the DOSITS website (see dosits.org) coming online in November 2002. Gail and I have been co-Principal Investigators ever since, with Peter, Jim, and me as the original subject matter experts for DOSITS, and Gail and colleagues at URI as the educational expertise, translating our "science-ese" for the general public.

DOSITS has continued to be supported primarily by the ONR, for which we are incredibly grateful. The website has grown from tens of pages of content to over 500 pages (Vigness-Raposa et al., 2021). Content is divided into three main sections: Science of Sound, People and Sound, and Animals and Sound. The difficulty level begins with basic content describing sound and its properties and how and why people and animals make and use sound. Content progresses through difficulty, reaching university level in some advanced topics where physics and mathematics are introduced. Galleries provide information inviting to all ages, with audio files of underwater sound sources (Audio Gallery), equipment descriptions (Technology Gallery), representative scientists (Scientist Gallery), and careers that use acoustic skills (Career Gallery).

Moreover, DOSITS resources have expanded to include webinars, structured tutorials, and professional development opportunities. Webinars have been ongoing since 2015, offering opportunities for participants to connect virtually with acoustic professionals. There were more than 3,134 registrations and 1,385 individual live connections from over 79 countries for the 2023 webinar series (several people participate in the DOSITS webinars in groups). As of fall 2024, there have been 38 webinars, which are recorded and openly available for nonconcurrent viewing (see bit.ly/47CRVbu).

I have continued to dedicate my life to helping build resources for scientists to communicate with the public. As scientists, we rarely receive training on how to have crucial conversations with the public or media personnel. It is difficult for nonscientists to understand the scientific process and the importance of peer review, particularly now in our immediate gratification culture. But I know we can continue to be creative and support multidisciplinary thinking to encourage serendipity in others.

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Contact Information

Kathleen J. Vigness-Raposa
kathy@inspireenvironmental.com

INSPIRE Environmental
513 Broadway
Suite 314
Newport, Rhode Island 02840, USA

Scattered Serendipities: How to Make Sense of Everything

Michael Vorländer

Random Walks from Astronomy to Acoustics

When I started writing this essay, I wondered how I could integrate the different interpretations of the term serendipity. Mostly, it is the observation of something you were not originally looking for that eventually leads to a new and surprising discovery. But it also refers to serendipitous moments in one's career that determine a pivot point in the decision tree of choosing A or B, with drastic consequences and repercussions in many ways.

We start in high school, where my main interest was math and physics. My most influential high-school teacher was a fascinating man with deep knowledge and an excellent teaching style that drew me even more into physics. By the way, there was also an influential music teacher at that school, and the serendipity was that she opened a door to a small room where musical instruments were kept, where I found my first drum kit!

The impetus to study physics in a five-year, single-track graduate program resulted from my passion for astronomy and particle physics. In my second year, in 1979, during a Sunday walk through a forest, I saw an elegant building labeled "Institute of Building Physics." What is that? My father, who was an architect, explained to me that it dealt with physics and engineering tasks in construction related to thermal and moisture insulation and acoustics. I applied at this institute as intern, was accepted, and assisted in various projects on sound insulation with porous absorbers and room acoustics. And it just so happened that I liked acoustics; it was something real and tangible. What about career opportunities in acoustics?

However, to complete my degree with a major in acoustics, I had to transfer to another university. The decision-making process was a confluence of two serendipitous moments that happened at the same time. First, my girlfriend Angelika (later my wife) moved to the city of Aachen to study. Second, RWTH Aachen University, Aachen, Germany, had a renowned acoustics institute headed by Heinrich Kuttruff. I knew of him from reading his book on room acoustics (Kuttruff, 1979) when I was still working as an intern. Now the decision was easy; moving to Aachen wasn't planned before but now it made a lot of sense.

Images and Scattering

My master's thesis under supervision of Heinrich Kuttruff in 1984 dealt with the spatial impression in concert halls. Mike Barron's "lateral energy fraction" is an objective quantity that correlates with the subjective impression of the apparent source width" (see Hochgraf, 2019, Table 1). One of the characteristics of a good concert hall is a sufficient amount of strong sidewall reflections as expressed in a high lateral fraction. Its application in the set of criteria in concert hall construction was not yet fully established in those days.

The task was to investigate the influence of the floor plan of the room on the lateral energy fraction. I implemented an image source model and examined room shapes. When the positions of the image sources were plotted for

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higher reflection orders, the result was a beautiful starry sky of image sources but with a drastically increasing number of reflection combinations, which led to needing astronomically large computer storage and computing times. It seemed like a good idea to get rid of the exponential increase in the construction of image sources; more on that serendipity later.

Another task was to investigate the influence of wall surface roughness on the angular distribution of reflected sound. Apart from some analytical solutions for surface scattering, measuring the reflected sound at a given sound incidence was the only possibility for any surface structures. Serendipitously, an ultrasonic source was available in the laboratory for scale-model experiments. Accordingly, flat plates with different arrangements of sticks and other small pieces on them were created and placed under an arrangement of sound source and microphone. The original aim was to measure the impulse response of the surface structure with various source-receiver arrangements so as to obtain information about the directional pattern of surface scattering. A digital oscilloscope was used to display an impulse response that was updated approximately every second. By looking at the impulse responses while moving the plate to make small adjustments, the now familiar random-incidence scattering coefficient emerged by serendipity.

The scattering coefficient is defined as the ratio between the diffusely scattered energy outside the specular ("incidence angle equals the reflection angle") direction and the total reflected energy. It was observed that the specular and the scattered sound components had very different characteristics. The specular sound changed very little due to the small movements of the plate, but the scattered component of the sound was subject to random amplitude and phase modulations (shown in **Figure 1**).

It was fun to move and rotate the plate and see this phenomenon in the impulse response. I then wondered if this could possibly be used to separate coherent and incoherent reflected sound. Yes, it was, and the end result years later was that a new method for measuring surface scattering was standardized in the International Organization for Standardization (ISO) 17497-1:2004 standard, which has big implications for geometrical-acoustic simulation techniques (ISO 17497-1:2004, 2004).

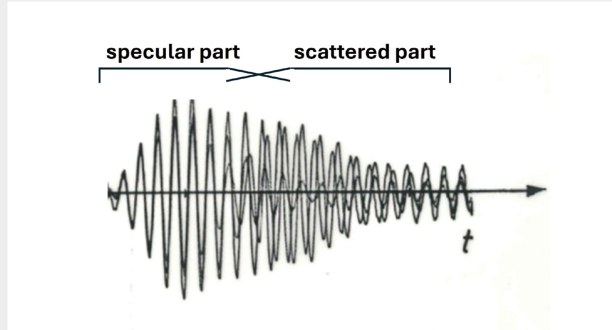

Figure 1. *Four bandpass-filtered reflections from a corrugated plate with a slightly shifted or rotated structure. The first part (specular component) stays coherent, whereas in the second part (scattered component), the four waveforms get out of phase during movement (Vorländer, unpublished figure).*

For the doctoral project, which began in 1985, Heinrich Kuttruff gave me absolute freedom to determine my own path. Inspired by his excellent teaching on the subject of room acoustics, I decided to study computer simulation of room acoustics. Ray tracing for use in room acoustics was known from programming on larger machines that filled entire rooms but doing this on a desktop PC with 640 kilobyte RAM was something else. It turns out that this worked well, and it was possible to simulate scattered and specular reflections and impulse responses at least with a temporal resolution of a few milliseconds. However, for auralization, which requires an impulse response with a sampling rate resolution (approximately 20 microseconds), working on a desktop PC was not feasible. Serendipitously, I discovered that the ray tracing algorithm could also be used to find image sources without the number of sources increasing exponentially and the calculation times being astronomically high, and this allowed me to use the PC. The key was the small algorithmic detail that the sequence of wall indices for each ray hitting one wall after the other contains exactly what is needed to find an audible image source. The temporal resolution can be as high as necessary. From then on, the path to auralization was paved.

Binaural Technology, Microphones, and Reverberation Chambers

The next serendipitous event in my career was my graduation to Doctor in Natural Sciences (Dr. rer. nat.) in 1989 and my move from the university to the Physikalisch-

Technische Bundesanstalt (PTB) in Braunschweig, the German National Metrology Institute, which is equivalent to the National Institute of Standards and Technology (NIST) in the United States. The move started with a phone call between Jürgen Meyer and Heinrich Kuttruff. Jürgen Meyer is a recognized expert in musical acoustics and room acoustics, but he also headed a larger department at PTB that included four laboratories.

They were actually looking for a postdoctoral researcher in the laboratory for audiology and microphone calibration. Dummy heads, ear simulators, headphone technology, primary microphone calibration, these were fields in which I had almost no experience. Nevertheless, Heinrich recommended me, and Jürgen invited me for a job interview. When I was offered the job as a research officer at the PTB, I had to think about my next career step. However, because there were excellent conditions in this laboratory and interesting projects, the decision was quickly made. We moved to Braunschweig, now with a family of five. It is not serendipity but rather divine providence that my son's names (Paul, Tobias, and Benjamin) bear the initials P, T, and B. Whether you believe in divine providence or not, it all seems to make a lot of sense! Just a little joke on the side: as a scientist, I shouldn't follow superstitions. But I've heard that it works even if you don't believe in it.

After two years of work on dummy heads and hearing thresholds, a new challenge arose when I became head of the laboratory for room and building acoustics in 1991. The serendipity here was that the experience with upcoming digital measurement technology, in particular with maximum-length sequence correlation methods, unexpectedly paved the way for the idea of showing myself in competitions in academic nomination processes. A combination of room acoustics, primary microphone calibration, and digital measurement technology was the core of my second doctoral thesis, the so-called habilitation. The habilitation is still an important academic procedure in some European countries and particularly in the natural sciences and humanities. It is an expression of the desire to pursue an academic career. One needs a university that supports the individual process. The habilitation involves a defense in which research and teaching skills must be demonstrated. During my employment at the PTB and supported by Jürgen Meyer, I was given the freedom to use my research for my habilitation. It was awarded by the Technical University of Dresden, Dresden, Germany, in 1996.

There were other surprises at the PTB. For example, during a sound power calibration procedure, it was found that the diffuse field equation between the source power and the average room sound pressure could be improved even after so many years of established room acoustics theory. In particular, an equation from Sabine's and Eyring's reverberation theory in room acoustics could be generalized to include not only wall absorption but also air attenuation.

The result of the work at the PTB was also a strong involvement in the international community, with many inspiring contacts with colleagues and friends that have remained to this day, another serendipity!

Back to Academic Roots: Scattering, Images, and All That Virtual Reality

Serendipity also means accepting the challenge when it presents itself on stage. The appointment in 1996 to a professorship at the RWTH as successor to my esteemed teacher Heinrich Kuttruff was certainly the best of all serendipitous moments. As far as my delving into acoustics as a whole is concerned, it came about in the fortunate constellation of events arising from all of my earlier serendipitous experiences where it felt like all previous events were coming together to form a somewhat logical construct. The swing back from the tasks related more to applied acoustics in a national metrology institute to the roots in fundamental science offered a great variety of research opportunities that are seemingly chaotic and unconnected, activities that included things such as room acoustics theory and simulation, digital measurement technology, electroacoustics, perception, and hearing research.

However, during my 28 years at the university, all these seemingly chaotic specializations in acoustics have become more and more condensed into a wonderful new field within acoustics, auralization. Sound sources (power spectrum, directivity), propagation (waves, rays), materials (absorption, scattering), and three-dimensional (3D) sound reproduction can be created for complex environments, allowing us to create virtual acoustic environments, often referred to as virtual auditory displays, in a computer (Vorländer, 2020). The serendipity is that this combination of principles and techniques could never be planned in advance. A certain breadth within all technical areas of acoustics is required, less deep specialization and more generalization. In retrospect, this happened through a chain of serendipities indeed.

Conclusion: What If This and That Had Not Happened?

Without an internship at a consulting firm, I probably wouldn't have studied acoustics. Without my wife, I would not have moved to Aachen to study with Heinrich Kuttruff. Without the freedom that Heinrich Kuttruff gave me, I would not have found my way into computer simulation. Without the ultrasound equipment at the institute at the time, I would not have seen the modulation phenomenon in surface-scattering impulse responses. Without the freedom that Jürgen Meyer gave me, I would not have been able to gain experience with acoustics in reverberation chambers, sound source characterization, and microphone calibration. Without my doctoral students and all the institute staff at RWTH Aachen University, I would not have been able to achieve anything. Without being part of a global network of wonderful people in the acoustics community, it wouldn't have been as much fun!

Whatever the alternatives might have been, I think it's good that things turned out this way.

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Contact Information

Michael Vorländer
mvo@akustik.rwth-aachen.de

Institute for Hearing Technology and Acoustics
RWTH Aachen University
52074 Aachen, Germany

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Appreciating the Flow of Serendipity: Channeling a Career in Architectural Acoustics

Lily M. Wang

I am a voracious consumer of leadership, management, and self-improvement books and training. I absolutely love learning; being a learner is core to how I perceive myself, an identity with which I highly resonate. Over the past five decades of my life, I have understood that if I study consistently, prepare diligently, practice persistently, and work hard, then I can achieve many of my personal and professional goals. Even so, things have not always gone as I hoped or dreamed that they would. Serendipity indeed has played a major role; something happenstance occurs that channels the direction of your life toward an altogether unexpected but immensely valuable and satisfying path. In my younger years, I never dreamed that I would become a faculty member in and leader of an academic unit in a college of engineering at a large public state university in the United States (see bit.ly/3z5oeUa), training future engineers in architectural acoustics and noise control. But I am so grateful to be where I am, following the flow of serendipity professionally and personally.

I have a distinct memory of the moment when my primary professional goal crystallized around designing concert halls. I was 15 years old, taking my first physics class at an all-female high school in Chattanooga, Tennessee. The textbook we were using for that class had text boxes sporadically arranged on the pages, highlighting interesting factoids or examples of physics in real life. One of those text boxes discussed how learning physics could be the foundation for a career in architectural acoustics, designing spaces for the performing arts. If my life were made into a movie, this would be the first scene in which music begins to play grandiosely to highlight this life-changing serendipitous moment. I could have glossed over that text box, but it was a serendipitous lightning bolt moment that set me on this professional career path. Thereafter, when people asked me what I was going to do with my life, I began proclaiming that I was going to be an acoustician and design concert halls.

Having been raised by strict immigrant parents from Asia, I knew I was expected to work hard and be accepted into an Ivy League undergraduate institution. I was admitted to Princeton University, Princeton, New Jersey (see princeton.edu). The university impressed me with its small student body, focus on liberal arts undergraduate education, and beautiful campus. There was no degree in acoustics at Princeton, so I instead decided to pursue civil engineering with a certificate in architecture because that seemed closest to setting me on the professional path I had declared for myself. I was excited to find and enroll in an architecture course called "Lighting and Acoustics." The acoustics portion was taught by Carl Rosenberg from the acoustical consulting firm Acentech (see acentech.com), who was an influential mentor to me and many others in our field. I greatly enjoyed this first class in acoustics!

With undergraduate graduation looming, I looked for a job with an acoustical consulting firm that worked in performing arts facilities or other architectural acoustics design. But I did not succeed in getting what I sought for; instead, in March of my senior year, I began nervously realizing that I should seriously consider graduate school as a next step. And so I applied to the graduate program

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in acoustics at the Pennsylvania State University, State College (see acs.psu.edu) and matriculated the next year.

My first semesters at Penn State did not go as well as I might have hoped. In fact, I was dismissed by my first graduate advisor, partially because I was still focused on getting the highest grades in graduate courses and not appropriately dedicated to research. This felt like a huge failure at the time, but looking back on it now, this event was indeed very serendipitous. Soon after that, another faculty member, Courtney Burroughs, took me under his wing. When I learned that I was awarded a National Science Foundation (NSF) Graduate Research Fellowship later that year, I was able to pursue a PhD with him, studying sound radiation from bowed violins using nearfield acoustic holography. I also received a grant through the Graduate Research Program for Women from AT&T Bell Laboratories and had the extreme fortune to work a summer at Bell Laboratories under the mentorship of Gary Elko and Jim West (see bit.ly/3YZibuL).

Let me be clear that, at that time, I did not want to get a doctoral degree. I wanted to design concert halls, and the people I admired who did that for a living unanimously advised that I only needed a master's degree, not a PhD. But the NSF fellowship covered my doctoral studies, so I did complete that, and although I had not sought to get a PhD, it did serendipitously open the next door for me to be able to apply for and receive the Hunt Postdoctoral Fellowship (see bit.ly/47imOCn) from the Acoustical Society of America (ASA).

I did not look for any other postdoctoral positions; the Hunt Fellowship was special. It would fund my dreams of going to Denmark and working at the Technical University of Denmark (DTU), Kongens Lyngby (see bit.ly/4cOR5K8) under the mentorship of Anders Christian Gade, a faculty member at that time who was doing fascinating work in the field of architectural acoustics and on-stage acoustics in performing arts facilities. DTU is also where the room acoustics modeling program ODEON (see odeon.dk) was founded and has been housed for many decades now. Because there were no acoustics faculty at Penn State specializing in architectural acoustics when I was studying there in the late 1990s, I felt that spending a year at the DTU would be unparalleled in immersing me more fully in the study of concert hall acoustics. And it was! Not only did I learn a great deal from my DTU mentors, but I also had the opportunity to travel all over Europe, visiting and attending concerts at renowned performing arts facilities, which helped me to understand and appreciate those spaces more deeply.

As one might expect, my travels throughout Europe led me into credit card debt. This was certainly a stressful scenario for me, but I was aware of what I was doing, consciously deciding to invest in impactful life experiences while I spent the year in Scandinavia and Europe.

The resulting financial stress, though, channeled me toward taking a tenure-track job offered by the University of Nebraska-Lincoln (UNL), starting in March 2000. I never wanted to be a faculty member, never! I was not aware of any tenured faculty member role models in the area or architectural acoustics. But in 1999, UNL was just starting a new architectural engineering program on their Omaha campus, and they were seeking a faculty member focused on architectural acoustics to join their team.

Another of their new faculty hires remembered me from being on the Penn State Engineering Graduate Student Board together; I was probably the only acoustics graduate student that she knew. But that serendipitous connection meant that they flew me from Copenhagen to Omaha in December 1999 to interview for the job. And I fit the bill, having a PhD (which I had never desired), and recently completed a postdoctoral position at the DTU focused on architectural acoustics (which was also a narrow channel that I slipped through). UNL offered me a tenure-track faculty position at a nice starting salary, which I definitely recognized would help tame my credit card debt.

I had never been to Nebraska before. I had to look up where it was on a map. I knew no one in the state. I thought I would just be there less than five years (long enough to not get tenure) and then I would finally join a consulting firm to work on concert halls. But I have now been at Nebraska for 25 years, longer than I have lived anywhere. UNL has supported me so well throughout these many years, giving me opportunities to teach and do research that I love in architectural acoustics and noise control. The Durham School of Architectural Engineering and Construction has outstanding financial resources, stemming from an endowment from Charles Durham (one of the cofounders of HDR, which is headquartered in Omaha; see bit.ly/3Z8sNaR). I have felt professionally challenged and personally happy, living in Omaha, Nebraska. This place is truly a hidden gem, one that I am becoming more intent on trumpeting more broadly because I now lead this academic unit!

When I arrived at Nebraska in 2000, I was still very intent on doing research in concert hall acoustics. I feel fortunate to have received a United States NSF CAREER Award that jump-started my academic career (see bit.ly/3TeYMlR), but I soon found that this was not a great area in which one could expect to have a funded research program in the United States. Instead, I embraced the realization that I could have greater impact if I focused instead on the acoustic environments of more common spaces, specifically classrooms and restaurants.

One serendipitous occurrence was that the Environmental Protection Agency (EPA) put out a call for research proposals in 2012 on healthy schools as part of its "Science to Achieve Results (STAR)" program at an excellent time in my career when I was ready to serve as principal investigator of a large grant with the right team of colleagues at the UNL. I am very proud of the work we accomplished through that EPA-funded grant. "Evidence-Based Interactions Between Indoor Environmental Factors and Their Effects on K-12 Student Achievement" (see bit.ly/3Xb9lHT).

A second serendipitous incident was in 2016 when a close college friend noticed my interest in restaurant acoustics through my social media accounts and subsequently followed up to connect me with her cousin who had just recently founded Soundprint (see soundprint.co), a smartphone app aimed at crowdsourcing sound levels at restaurants. My collaboration with Soundprint has been exciting; although the Covid pandemic did upend that work for a while, I am thrilled that my research group is making inroads into that particular area again, with Soundprint as a research partner.

And so it is that I have not yet fulfilled the dream I proclaimed in my teenage years to be designing concert halls. Well, we all have our fair share of disappointments. At this stage of my life, though, it is easy to look back on the rocks in the stream and be tremendously grateful for them; I would not change any part of the flow I have experienced. I may have been disappointed by many of the unexpected turns and challenges at the time, but they channeled my career through serendipity down a stream that has been deeply fulfilling, including the opportunity to serve the ASA as vice president (2015–2016) and president (2018–2019). I believe now that I would have been a terrible acoustical consultant; working as an educator and researcher in the field of architectural acoustics and noise control has been more rewarding than I could have dreamed.

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Contact Information

Lily M. Wang
lilywang@unl.edu

Durham School of Architectural Engineering and Construction
University of Nebraska-Lincoln
Omaha, Nebraska 68182-0816, USA

Predicting Sound Propagation in the Atmosphere

D. Keith Wilson

My career in acoustics began with an instance of serendipity. On receiving a BA degree in physics from Carleton College, Northfield, Minnesota in 1985, I was inclined toward applied physics, with optics and electromagnetics seemingly good possibilities. So I enrolled in the master's program in electrical engineering at the University of Minnesota, Minneapolis. While searching for a research assistantship, I serendipitously met Robert F. Lambert, a long-time member of the Acoustical Society of America (ASA), who was investigating the nonlinear properties of acoustic porous media. This turned into a master's thesis, and soon I took on the professional identity of "acoustician."

But this article is mainly about a different instance of serendipity in my career, namely, how my research in acoustics came to focus on the randomness and challenges of predicting sound propagation through the atmosphere. This focus arose largely from a couple formative experiments early in my career, which then set the stage for a key serendipitous encounter. In the following, I describe the two experiments followed by the serendipitous encounter.

The first of the experiments occurred as a PhD student. I had enjoyed my initial foray into acoustics so much that I enrolled in the Pennsylvania State University Graduate Program in Acoustics, State College, for my PhD. My thesis advisor was Dennis W. Thomson of the Meteorology Department, with whom I studied the intersection between acoustics and the weather. I found atmospheric acoustics compelling because it involves phenomena that can be experienced in our day-to-day lives if we observe closely enough, for example, hearing a distant train or roadway when the wind direction is right or the quiet of a soundscape with freshly fallen snow.

The experiment was simple. A subwoofer and a very powerful amplifier were placed near a barn at the Penn State agronomy research center, with microphones 750 m away. The purpose was to study the variation of long-range sound transmission with changing weather conditions. The sound level was monitored around the clock over several consecutive days during the summer and then during the fall. My main task was to write the BASIC program that retrieved and logged the data every minute from a spectrum analyzer.

When plotted over the course of several days, the data showed a clear trend, with the sound level rising each night and falling each day. This was not unexpected. At night, radiative cooling of the ground often leads to a temperature inversion (cold air near the ground, with a positive vertical temperature gradient), thus leading to downward refraction and ducted propagation. During the day, solar heating of the ground creates a temperature lapse (negative temperature gradient) condition, leading to upward refraction. Rather more surprisingly to me, superimposed on these trends were frequent, strong, random variations up to about 10 dB. Although some previous researchers, such as Ingard (1953), had noticed and remarked on this variability, by the 1980s, researchers had only begun to

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work systematically on experiments and theory to describe it (e.g., Daigle et al., 1986).

That was the first experiment I mentioned earlier. For the second experiment, fast forward about 10 years from my PhD student days. I was then working at the United States Army Research Laboratory. The Army Research Office organized a large, multinational experiment called CASES '99 to study the nighttime near-ground atmosphere. Dozens of organizations collaborated to deploy, at a site on the Great Plains in southeast Kansas, an array of tall, heavily instrumented towers, weather balloons and kites, and remote-sensing systems such as radar and sodar. Recognizing this opportunity to leverage the high-resolution atmospheric characterization, my colleagues John Noble and Mark Coleman simultaneously fielded loudspeakers and microphones to measure sound propagation over distances up to 1,300 m. Large, seemingly random variations in sound levels were observed as in the experiment I had analyzed years earlier. Astoundingly, even with the excellent coincident meteorological observations extending to hundreds of meters above the ground, the observed levels and their variations could not be consistently predicted, even with a state-of-the-art numerical method such as the parabolic equation (Wilson et al., 2003). This experiment had seemed like the best-case scenario from the standpoint of achieving good agreement between acoustic propagation model predictions and sound level measurements: flat, homogeneous ground, stable nighttime atmospheric conditions, and the best meteorological data feasible.

Now the instance of serendipity to which I have been leading. A few years later, on a dreary, muddy December day, I found myself at Ft. Drum in upstate New York. By this time, I had become involved in programming graphical interfaces to help nonexpert users such as soldiers apply the latest acoustic propagation models to real-world scenarios. It's not often that a PhD scientist trains soldiers directly! But the brigade commander was quite enthusiastic about having his unit learn new things. During the training, I serendipitously happened to overhear two soldiers converse about whether they should place any trust in the slick software I had worked so hard to develop. As I recall, I provided a cursory response that, of course, no model is perfect, but this was state-of-the-art and had been extensively compared with experiments. Reflecting later, I realized the inadequacy of my response. Sure, the physics of the wave equation is well established and numerical methods are available that can solve it accurately. But lacking suitable input data, even good models can produce poor results. And, as I learned during those earlier experiments, sound propagation exhibits considerable randomness and has limited predictability. As an expert, I had a decent sense of the model limitations. But how could that understanding be conveyed to nonexperts? Can the limitations due to uncertainties in inputs such as the atmosphere and ground state be meaningfully quantified? I had gone to Ft. Drum to instruct the soldiers but received an unexpected assignment from them.

For an initial effort at addressing the predictive limitations of the propagation models (Wilson et al., 2008), my collaborators and I made extensive use of large-eddy simulation (LES), a computational technique used to simulate turbulence in the atmosphere. The LES, when combined with the acoustical modeling, provided "ground truth" for propagation through a dynamic, fully three-dimensional atmosphere, which could then be compared with predictions based on more limited meteorological data as would typically be available in practice.

Here are some of the practical questions we aimed to answer: What happens when, say, there are variations in the wind and temperature profiles along the propagation path that cannot be observed? Or when the profiles are, say, half-hour averages around the time of the actual sound level measurement or event? Or when the profiles are from a nearby but different location? We found, for example, that even with accurate meteorological measurements from a location and time very close to the propagation path, sound level predictions have inherent random errors of about 6-8 dB. Fortunately, the errors do generally diminish when *mean* meteorological measurements (over an interval of, say, a half hour) are used to predict *mean* sound levels over the same time interval. But random variability of the atmosphere and the sensitivity of sound waves to this variability make it infeasible to accurately predict the propagation at a particular time and place.

In a further instance of serendipity, it was around this time that I first met Chris Pettit, then a new faculty member at the United States Naval Academy, Annapolis, Maryland, who had responded to a solicitation I put out regarding atmospheric acoustics research. Chris had previously performed research on uncertainty quantification (UQ) in aerodynamics and turbulence and quickly grasped that the methods he had learned for statistically characterizing errors of predictions from complex, nonlinear models would be valuable for sound propagation because the models are highly sensitive to inputs varying in time and space that cannot be exactly characterized. Together, we worked on a number of approaches to reducing the number of model runs needed to accurately predict sound levels, while efficiently quantifying the impacts of uncertainty in the wind and temperature profiles, turbulence spectra, and ground properties (e.g., Wilson et al., 2014; Martinelli et al., 2023).

An *Acoustics Today* article (Wilson et al., 2015) provided an opportunity to summarize the perspective I had formed over the previous couple of decades. Looking back, I arrived at this perspective through a serendipitous sequence of events, beginning with experiments having initially surprising results. These experiments provided a context for later interactions with soldiers who wanted to know if they could rely on "black box" computer models. The questions that arose developed into productive research thanks to seemingly chance collaborations and discussions with many outstanding colleagues. Unexpected results and challenges become valuable opportunities for new learning and discovery when we are prepared to see them through a different perspective.

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Contact Information

D. Keith Wilson
d.keith.wilson@usace.army.mil

United States Army Engineer Research and Development Center
Hanover, New Hampshire 03755, USA

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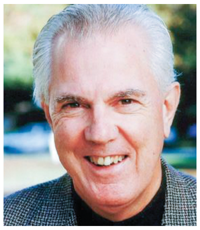
Serendipitous Observations in the Study of Auditory Perception

William A. Yost



Serendipity, what is it? To me, serendipity is the luck of finding or creating interesting or valuable things somewhat by chance. I believe I have experienced such serendipitous luck, but I do not think serendipity for me, as a scientist, occurred randomly. "Creating interesting or valuable things" does not occur in a vacuum. The "creation" is likely due to a whole host of preceding events that the scientist has been studying and thinking about. Of relevance for this essay is the idea of a zeitgeist. Zeitgeist ("spirit of the age") is a German term that to me describes an invisible idea dominating the characteristics of a given epoch in history. The "characteristics of a given epoch in history" can set the stage for a serendipitous creation.

Several of my serendipitous moments occurred when I realized that a current way of studying auditory perception probably needed to change and there was a "zeitgeist" that I experienced suggesting what the change might be. One of those moments of serendipity occurred when I realized that a great deal of the history of the study of auditory perception did not deal with what people actually say they "hear." Instead, a prevailing view of sensory perception after the nineteenth century was that the mind (brain) gains knowledge of the world based on the brain's ability to determine objects in the world via the senses (e.g., see Boring, 1942). It was not long before studies of auditory perception investigated the perception of the acoustic properties of sound (e.g., frequency, intensity, spectrum, duration, location) and the attributes associated with those acoustic properties (e.g., pitch, loudness, timbre, perceived duration, perceived location).

In 1989, I intended to write a textbook on sensory processing, explaining this history based on what I had learned as the Program Director for the Sensory Physiology and Perception Program of the National Science Foundation (NSF) in the early 1980s. This NSF program was responsible for funding any meritorious proposal-seeking support to investigate the biology and/or perception associated with any sensory system, and I learned a lot about sensory systems in this challenging job.

There were, of course, already such sensory-processing textbooks, some of which were very good. However, they were usually not "built" around a theme, and students often complained along the lines of, "Well it must be Tuesday, as I see the next topic is smell." I thought I had a theme based on the history I mentioned above that the brain uses sensory systems to process objects in the world and their attributes. I outlined chapters about vision based on light produced and reflected by objects and the perceptual attributes of this light.

However, when I started to do the same thing for hearing, I had my serendipitous moment in which I realized that almost nothing was known about objects that produce audible sound (the human voice and musical instruments were exceptions) or what perceived sound indicates about the objects that produce sound. I realized that most, if not all, people could, if asked, indicate if the pitch of a sound is low or high or if a sound is loud or soft. However, that is not what is usually voluntarily reported when one indicates what one hears. Instead, listeners often report

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the object (*source*) that produced the sound, such as the *car* screeched, the *baby* cried, the *ball* bounced, or the *leaves* on a tree rattled. Thus, auditory perception has a lot to do with the sources of sounds, and little seemed to be known about the perception of sound sources per se. In addition, how do we possibly sort out what the objects are when more than one object produces sound at about the same time?

Based on this bit of serendipity, I immediately stopped work on a sensory sciences' textbook and wrote an article, *Auditory Image Perception and Analysis* (Yost, 1991), explaining my serendipitous conclusion that "hearing" was about the objects that produced sound, not just about the sound itself. I am deeply indebted to Dave Green, as he gave me good ideas and the confidence to try to publish a nonresearch-based opinion piece.

Of course, I was not the only one making this observation at this time, with the most compelling of those being *Auditory Scene Analysis* by Al Bregman (1990), a book that clearly captured the imagination of sensory and perceptual scientists. There was obviously a zeitgeist in the late 1980s early 1990s because none of us who wrote about our serendipity at this time were aware that others were also having the same ideas. The challenges of understanding the perception of sound sources became the topic of several more of my publications, the organizing theme of all my research after 1990, and the generator of ideas for most of my experiments.

As I indicated previously, my efforts to understand sound-source perception had a profound influence on what I thought was important to know about auditory perception. This was during a period that followed major new discoveries of how the inner ear and auditory nerve process sound (e.g., Brownell, 2017). Consequentially, studies of auditory perception seemed to be related mainly to the peripheral processing of sound.

When I moved to Arizona State University (ASU), Tempe, I had the opportunity to work with Michael Dorman and those in his laboratory on a series of papers investigating cochlear implant (CI) patients' performance in different spatial-hearing tasks (see Pastore et al, 2024, for the most recent paper). The success of the CI demonstrated to me that the auditory periphery (an "ear") is not required to perceive sound but a *brain* is.

Indeed, a type of serendipity occurred when I realized sound-source perception was about *what* and *where* sound sources are, and the *brain*, not the auditory periphery, determined *what* and *where* sound sources are. As I developed these ideas about sound-source perception, I also realized that to perceive sound sources, it was not necessary to be able to identify (label) *what* a sound source was. When Bob Lutfi wrote a chapter (Lutfi, 2007) for the book on sound-source perception that I coedited (Yost et al., 2007), we argued about the extent to which sound-source identification was important. Bob is an astute scholar of auditory perception, so his ideas about sound-source identification stayed with me.

My laboratory's research on sound-source localization (*where* sound sources are) in a real world of moving listeners and sound sources convinced me that to localize *where* a sound source is in the real world, the *brain* must combine information derived from the auditory-spatial cues with that derived from the position of the head (see Pastore et al., 2020; Yost et al., 2021, for reviews). The position of the head must be specified in relationship to the world surrounding the listener and the objects in that world.

These observations and ideas led to what was for me a serendipitous conclusion, that determining *what* a sound source is and *where* it is requires the *entire brain*, not just the *auditory brain*, and almost nothing seemed to be known about how the *entire brain* does either. Clearly, I was not the only one making this observation, so I benefitted from a zeitgeist regarding how little is known about the *entire brain* and auditory perception.

My final bit of serendipity was the realization of how crucial memory is for successfully functioning in an auditory world. Auditory memory is an understudied and, in my opinion, underappreciated aspect of auditory perception. Earlier in this essay, I observed that listeners have little difficulty knowing the source of a sound when a *car* screeched, a *baby* cried, a *ball* bounced, or the *leaves* on a tree rattled. I had the serendipitous realization, however, that the ability to identify the sources of these sounds immediately with little or no effort requires that key features of the sounds and their labels had already been stored in memory and that when a sound occurs, the appropriate labels for its source can be easily recalled from memory. *What* are those auditory features, *where* is this information stored, *how* is the information stored and then retrieved, *when* in the time frame of auditory processing do these events take place? As far as I know, the answers to these key scientific questions are poorly understood, if they are understood at all.

What about the *brain* and the issue of *where* sound sources are located? I already mentioned our arguments that sound-source localization in the real world requires combining information about the auditory-spatial cues with that from the position of the head (again, see Pastore et al., 2020; Yost et al., 2021, for reviews). The 2014 Nobel Prize in Physiology and Medicine was awarded to John O'Keefe, Eduard Moser, and May-Britt Moser for their work on spatial memory ("Cells that constitute a positioning system in the brain" from their Nobel citation; see bit.ly/4hcGEDK). When I first learned of the award, I did not think their work had much to do with my interests in auditory perception, even though I had read a few of O'Keefe's papers in the early 1980s. It wasn't long until I had a serendipitous moment realizing their work does have a great deal to do with issues of the *entire brain*'s ability to determine *where* sound sources are located.

The Nobel Laureates and others have described in some detail the formation of *cognitive spatial maps* in the hippocampus and surrounding entorhinal cortex (e.g., O'Keefe, 1991). Indeed, *cognitive spatial maps* are what you depend on to navigate in your bedroom at night when you can barely see, and what you can recall about the spatial layout of your bedroom even when you are not in it.

A thought experiment might demonstrate the possible impact of *cognitive spatial maps* for determining *where* sound sources are located. Imagine that you are awakened in the middle of the night in your totally dark bedroom by a brief banging sound. The auditory-spatial cues led you to realize that the sound came from directly in front of you as you lie in your bed, at slightly below the height of you in your bed, and at some distance from you. You immediately conclude, with little effort, that the sound came from the bathroom; perhaps the picture fell off the wall.

How did you conclude that the picture fell off the wall in your bathroom? Your brain would be able to use the auditory-spatial cues to determine that the source of the sound was directly in front of your head as you lay in bed. Your *cognitive spatial map* might indicate that there is a picture on the wall in the bathroom directly in front of you as you lay in bed. Note that the *cognitive spatial map* does not indicate the position of objects (e.g., the picture) just relative to your head, but relative to the room and the other objects in it, a condition that is required to localize the sources of sounds in the real world (O'Keefe, 1991). Several different sensory cues have been shown to generate *cognitive spatial maps*, but it is not clear if auditory cues are used. And, if so, how? Do such maps assist in sound-source localization as the thought experiment suggests? If so, how?

My conclusion from my recent serendipitous episodes is that knowing a lot more about auditory memory seems to be a worthwhile research endeavor, which I would peruse if I wasn't retired. A pursuit, which will probably be advanced by many additional serendipitous moments, which others, not I, will hopefully have.

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Contact Information

William A. Yost
william.yost@asu.edu

9119 N. 117th Way
Scottsdale, Arizona 85259, USA